Anne Arundel County Public Schools

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Earth Space Systems Science

Unit 3: The Hydrosphere

Earth/Space Systems Science
Unit III: The Hydrosphere

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Earth/Space Systems Science
Unit III: The Hydrosphere

Description

The processes that occur in the atmosphere and hydrosphere are connected. The atmosphere and the oceans are the two large fluid reservoirs of planet Earth. Together with the lithosphere, these spheres have produced an environment that led to the development of life on Earth. The hydrosphere is the reservoir for the Earth's water. Students progress through an examination of the Earth's water reservoirs, the great ocean currents, energy flow in the hydrosphere, and the implications for weather and climate. Learning activities lead students through modeling, data collection and analysis, and manipulation and laboratory investigation of the physical processes that govern the cycling of matter and the flow of energy through this system.

WHAT DOES THE RESEARCH SAY?

Water cycle

Students' ideas about conservation of matter, phase changes, clouds, and rain are interrelated and contribute to understanding the water cycle. Students seem to transit a series of stages to understand evaporation. Before they understand that water is converted to an invisible form, they may initially believe that when water evaporates it ceases to exist, or that it changes location but remains a liquid, or that it is transformed into some other perceptible form (fog, steam, droplets, etc.) (Bar, 1989; Russell, Harlen, & Watt, 1989; Russell & Watt, 1990). With special instruction, some students in 5th grade can identify the air as the final location of evaporating water (Russel & Watt, 1990), but they must first accept air as a permanent substance (Bar, 1989). This appears to be a challenging concept for upper elementary students (Sere, 1985). Students can understand rainfall in terms of gravity in middle school but not the mechanism of condensation, which is not understood until early high school (Bar, 1989).

Heat transfer

Middle-school students do not always explain the process of heating and cooling in terms of heat beingtransferred (Tiberghien, 1983; Tomasini & Balandi, 1987). Some students think that "cold" is being transferred from a colder to a warmer object, others that both "heat" and "cold" are transferred at the same time. Middle and high-school students do not always explain heat-exchange phenomena as interactions. For example, students often think objects cool down or release heat spontaneously—that is, without being in contact with a cooler object (Kesidou, 1990; Wiser, 1986). Even after instruction, students don't always give up their naive notion that some substances (for example, flour, sugar, or air) cannot heat up (Tiberghien, 1985) or that metals get hot quickly because "they attract heat," "suck heat in," or "hold heat well" (Erickson, 1985). Middle school students believe different materials in the same surroundings have different temperatures if they feel different (for example, metal feels colder than wood). As a result, they do not recognize the universal tendency to temperature equalization (Tomasini & Balandi, 1987). Few middle and high-school students understand the molecular basis of heat transfer even after instruction (Wiser, 1986; Kesidou & Duit, 1993). Although specially designed instruction appears to give students a better understanding about heat transfer than traditional instruction, some difficulties often remain (Tiberghien, 1985; Lewis, 1991).

Energy forms and energy transformation

Middle and high-school students tend to think that energy transformations involve only one form of energy at a time (Brook & Wells, 1988). Although they develop some skill in identifying different forms of energy, in most cases their descriptions of energy change focus only on forms that have perceivable effects (Brook & Driver, 1986). The transformation of motion to heat seems to be difficult for students to accept, especially in cases with no obvious temperature increase (Brook & Driver, 1986; Kesidou & Duit, 1993). Finally, it may not be clear to students that some forms of energy, such as light, sound, and chemical energy, can be used to make things happen (Carr & Kirkwood, 1988).

Energy conservation

The idea of energy conservation seems counter-intuitive to middle- and high-school students who hold on to the everyday use of the term energy, but teaching heat-dissipation ideas at the same time as energy-conservation ideas may help alleviate this difficulty (Solomon, 1983). Even after instruction, however, students do not seem to appreciate that energy conservation is a useful way to explain phenomena (Brook & Driver, 1984). Middle- and high-school students tend to use their intuitive conceptualizations of energy to interpret energy conservation ideas (Brook & Driver, 1986; Kesidou & Duit, 1993; Solomon, 1985). For example, some students interpret the idea that "energy is not created or destroyed" to mean that energy is stored up in the system and can even be released again in its original form (Solomon, 1985). Although teaching approaches that accommodate students' difficulties about energy appear to be more successful than traditional science instruction, the main deficiencies outlined above remain despite these approaches (Brook & Driver, 1986; Brook & Wells, 1988).

AAAS. *Benchmarks on Line*. The Research Base. Available:

http://www.project2061.org/tools/benchol/bolframe.htm

Many of these lessons need the CD- Visit to an Ocean Planet. This CD may be ordered or the activities may be downloaded from

Available: http://topex-www.jpl.nasa.gov/education/cdrom.html

Key questions for this unit are:

1. Why do ocean currents form?
2. How does light energy from the sun relate to energy flow in the hydrosphere?
3. What role does frozen water (the cryosphere) play in the Earth system?
4. How does the interaction between the atmosphere and hydrosphere affect our climate?

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Key Concepts

- Heating of earth's surface and atmosphere by the sun drives convection within the atmosphere and oceans, producing winds and ocean currents. (NSES, p. 189)

- Global climate is determined by energy transfer from the sun at and near the earth's surface. Dynamic processes such as cloud cover and rotation the earth's and static conditions such as the position of mountain ranges and oceans influence this energy transfer. (NSES, p. 189)

- The earth is a system containing essentially fixed amount of each chemical atom or element. Each element can exist in several chemical reservoirs. Each element on earth moves among reservoirs on the solid earth, oceans, atmosphere, and organisms as part of the geochemical cycles. (NSES, p. 189)

- Movement of matter between reservoirs is driven by earth's internal and external sources of energy. These movements are often accompanied by a change in the physical and chemical properties of the matter. (NSES, p. 189)

- Life is adapted to conditions on the earth, including the force of gravity that enables the planet to retain an adequate atmosphere, and an intensity of radiation from the sun that allows water to cycle between liquid and vapor. (AAAS, p. 70)

- Weather (in the short run) and climate (in the long run) involves the transfer of energy in and out of the atmosphere. Solar radiation heats the landmasses, oceans, and air. Transfer of heat energy at the boundaries of the atmosphere, the landmasses, and the oceans results in layers of differential temperatures and densities in both the oceans and the atmosphere. The action of gravitational forces on regions of different densities causes them to rise or fall - and such circulation, influenced by rotation of the earth, produces winds and ocean currents. (AAAS, p. 70)

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CONTENT OUTLINE

The Hydrosphere

I. Interaction between the Atmosphere and Hydrosphere
   - A. Cryosphere
     1. Sea Ice
   - B. Daily and seasonal breezes
     1. Sea and land breeze
     2. Monsoon

II. Wind-driven Currents
   - A. Global winds
   - B. Coriolis effect

III. Density
   - A. Temperature
   - B. Salinity

IV. Vertical Circulation
   - A. Density Driven currents
     1. upwelling and downwelling

V. Transfer of Energy
   - A. The Global Conveyer Belt
     1. Weather and Climate
   - B. El Nino and La Nina

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LESSON	TITLE	STUDENT OUTCOME(S)	SEVEN PERIOD DAY	FOUR PERIOD DAY
1	THE OCEANS AND HEAT TRANSFER	THE STUDENT WILL BE ABLE TO DESCRIBE HOW ENERGY FLOWS THROUGH THE GLOBAL WATER CYCLE BY COLLECTING EXPERIMENTAL DATA ON PHASE CHANGES AND CREATING A SYSTEMS DIAGRAM.	TWO	ONE
2	SEA ICE	1. THE STUDENT WILL BE ABLE TO DETERMINE THE EFFECT OF SEA ICE ON THE ATMOSPHERE BY CONDUCTING A LABORATORY INVESTIGATION AND ANALYZING DATA. 2. THE STUDENT WILL BE ABLE TO CORRELATE THE PRESENCE OF SEA ICE WITH OCEAN CIRCULATION PATTERNS BY READING A TECHNICAL PASSAGE AND VIEWING A COMPUTER SIMULATION.	TWO	ONE
3	DAILY SEA-LAND BREEZES AND CLIMATE	1. THE STUDENT WILL BE ABLE TO EXPLAIN THE FORMATION OF SEA-LAND BREEZES BY ANALYZING DAILY WEATHER INFORMATION AND SATELLITE IMAGES. 2. THE STUDENT WILL BE ABLE DESCRIBE THE INFLUENCE OCEANS HAVE ON CLIMATE BY READING A TECHNICAL PASSAGE AND COMPARING COASTAL AND INLAND CLIMATES.	ONE	ONE
4	MONSOONS	1. THE STUDENT WILL BE ABLE TO IDENTIFY THE CHARACTERISTICS OF A MONSOON BY ANALYZING SATELLITE DATA.	ONE	ONE

		2. The student will be able compare monsoon and sea breezes by completing a graphic organizer and writing a journal entry.		
5	Wind-Driven Circulation	1. The student will be able to explain the impact of global winds and the Coriolis effect on ocean circulation. 2. The student will be able to predict the location of surface currents by analyzing global wind patterns.	Two	One
6	Ocean Currents	The student will be able to explain the role of ocean currents in heat transfer by analyzing sea surface temperatures.	Two	One
7	Boundary Currents	1. The student will be able to compare ocean boundary currents by analyzing the relationship among global winds, water temperatures and coastal climates. 2. The student will be able to explain how ocean currents affect coastal climates by analyzing data.	Two	One
7A	Ekman Spiral *G/T or Honors*	The student will be able to determine the direction of a surface current by interpreting Ekman spiral and Ekman transport.	*Two*	*One*
7B	Convergence and Geostropic Currents	The student will be able to explain the effect of Ekman Transport and the Coriolis effect on convergence and the formation of geostrophic currents by analyzing ocean	*Two*	*One*

	G/T or Honors	topography and creating a system diagram.		
8	Density	The student will be able to determine factors that influence the density of water by performing laboratory investigations.	Two	One
9	Vertical Distribution	The student will be able to predict the structure of the deep ocean waters by applying the results of laboratory investigations.	Two	One
10	Causes of Deep Ocean Currents	The student will be able to hypothesize the causes of deep ocean currents by performing laboratory investigations and then comparing their results to oceanic data.	Three	Two
11	Density Driven Vertical Ocean Currents	1. The student will be able to compare wind-driven and density-driven circulation by analyzing the results of laboratory investigations. 2. The student will be able to describe how differences in water density influence vertical ocean circulation by analyzing temperature and salinity diagrams.	Two	One
12	Upwelling	The student will be able to describe the causes and effects of upwelling by analyzing the relationship among wind direction, Coriolis effect and sea surface temperatures.	Two	One
13	The Global Conveyer Belt	The student will be able to explain the influence of the global conveyor belt on climates by analyzing interaction between	One	One

		SURFACE CURRENTS AND DEEP OCEAN CURRENTS AND CREATING A SYSTEMS DIAGRAM.		
14	CLIMATE, WEATHER AND SEASON VARIABILITY	1. THE STUDENT WILL BE ABLE TO IDENTIFY TRENDS THAT SIGNAL A CHANGE IN THE CLIMATE BY ANALYZING SATELLITE IMAGERY AND EXAMINING LONG-TERM WEATHER PATTERNS. 2. THE STUDENT WILL BE ABLE TO DETERMINE HOW SEASONAL CHANGES IN SOLAR RADIATION AFFECT SEA LEVEL HEIGHTS BY CONDUCTING A LABORATORY INVESTIGATION AND ANALYZING SATELLITE IMAGERY.	TWO	ONE
15	EL NINO/LA NINA	THE STUDENT WILL BE ABLE TO DESCRIBE THE CAUSES AND EFFECTS OF EL NIÑO/SOUTHERN OSCILLATION BY READING TECHNICAL SELECTIONS AND ANALYZING DATA.	TWO	ONE
16	BENCHMARK ASSESSMENT		ONE	ONE
A	STRUCTURE OF THE HYDROSPHERE *SUPPLEMENTAL LESSON*	THE STUDENT WILL BE ABLE TO DESCRIBE THE STRUCTURE OF THE HYDROSPHERE QUANTITATIVELY BY ANALYZING THE RESERVOIRS AND FLUXES.	*TWO*	*ONE*
APPROXIMATE NUMBER OF TIME BLOCKS			29	17

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Materials per group of four

Aluminum foil: 2 cm x 2cm
Beaker, 1000, 600, 400, 50 mL
Blank world map - 4
Books - 5
Bunsen burner
Clothes pins or small clamps - 2
Colored pencils
Container, large clear
Containers, three large to store water
Cork stopper
Corn syrup
Diagram of Global Conveyor Belt - 4
Dish detergent
Drinking straw- 2
Earth's heat budget diagram - 4
Erlenmeyer flask, small, medium
Eye droppers – 2
Filter paper
Food coloring: red, green, and blue
Glass dish, approximately 9 x 13 x 3 inches
Glass jars with lids - 2
Graduated cylinder
Graph paper- 4
Hair dryer
Heat lamp
Hot plate
Hydrometer or Salinity meter
Ice cubes or chemical cold pack
Images of the global showing sea level heights - 4
Map of sea surface temperatures - 4
Maps of sea surface temperatures, wind speed and wind direction - 4
Ocean current maps - 4
Oil
Outdoor Temperature vs. Time graph - 4
Outdoor Temperature, Wind Direction vs. Time graph - 4
Petri dish
Red and blue colored pencils - 4
Ring stand with clamp
Rock
Rock salt
Salt
Salt water: 20 ppt, 30 ppt, 40 ppt
Sand
Scissors
Sea surface salinities map - 4
Sea surface temperatures map - 4
Shampoo
Spoon
Stirring rod
Stopwatch
Syrup
Temperature-Salinity Diagram - 4
Ten colored-paper disks
Thermometer or CBLs/computer and temperature probe - 2
Topographic map-4
Tubing, plastic, at least 1 ft
Turntable
Water cycle diagram-4
Water, distilled and fresh
Wire mesh pad
World map showing latitude/longitude lines - 4
World map with ocean currents worksheet - 4
Zip-lock bags, small -2

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LESSON 1: THE OCEANS AND HEAT TRANSFER

Estimated Time: Two fifty-minute blocks

Indicator(s) Core Learning Goal 1:

1.1.2 The student will modify or affirm scientific ideas according to accumulated evidence.

1.2.3 The student will formulate a working hypothesis.

1.2.4 The student will test a working hypothesis.

1.2.7 The student will use relationships discovered in the lab to explain phenomena observed outside the laboratory.

1.4.1 The student will organize data appropriately using techniques such as tables, graphs, and webs (for graphs: axes labeled with appropriate quantities, appropriate units on axes, axes labeled with appropriate intervals, independent and dependent variables on correct axes, appropriate title).

1.4.2 The student will analyze data to make predictions, decisions, or draw conclusions.

Indicator(s) Core Learning Goal 2:

2.3.1 The student will describe how energy and matter transfer affect Earth systems. Assessment limits (at least) -Atmospheric circulation (heat transfer systems – conduction/convection/radiation, phase change, latent heat, pressure gradients, general global circulation, Coriolis effect)

2.3.2 The student will explain how global conditions are affected when natural and human-induced change alter the transfer of energy and matter. Assessment limits: Ocean-atmosphere land interactions (current changes, continental movement, El Nino, La Nina).

Student Outcome(s):

The student will be able to describe how energy flows through the Global Water Cycle by collecting experimental data on phase changes and creating a systems diagram.

WHAT DOES THE RESEARCH SAY?

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At grades 9-12, students focus on matter, energy, crustal dynamics, cycles, geochemical processes, and the expanded time scales necessary to understand events in the earth system. Driven by sunlight and earth's internal heat, a variety of cycles connect and continually circulate energy and material through the components of the earth system. Together, these cycles establish the structure of the earth system and regulate earth's climate. In grades 9-12, students review the water cycle as a carrier of material, and deepen their understanding of this key cycle to see that it is also an important agent for energy transfer. Because it plays a central role in establishing and maintaining earth's climate and the production of many mineral and fossil fuel resources, the students' explorations are also directed toward the carbon cycle. Students use and extend their understanding of how the processes of radiation, convection, and conduction transfer energy through the earth system. National Research Council, *National Science Education Standards* (1996).

Earth systems have internal and external sources of energy, both of which create heat. The sun is the major external source of energy. Heating of earth's surface and atmosphere by the sun drives convection within the atmosphere and oceans, producing winds and ocean currents. Global climate is determined by energy transfer from the sun at and near the earth's surface. This energy transfer is influenced by dynamic processes such as cloud cover and the earth's rotation, and static conditions such as the position of mountain ranges and oceans
National Research Council, *National Science Education Standards* (1996).

Weather (in the short run) and climate (in the long run) involve the transfer of energy in and out of the atmosphere. Solar radiation heats the land masses, oceans, and air. Transfer of heat energy at the boundaries between the atmosphere, the land masses, and the oceans results in layers of different temperatures and densities in both the ocean and atmosphere. The action of gravitational force on regions of different densities causes them to rise or fall—and such circulation, influenced by the rotation of the earth, produces winds and ocean currents.
AAAS, *Benchmarks for Science Literacy* (1993).

Brief Description:

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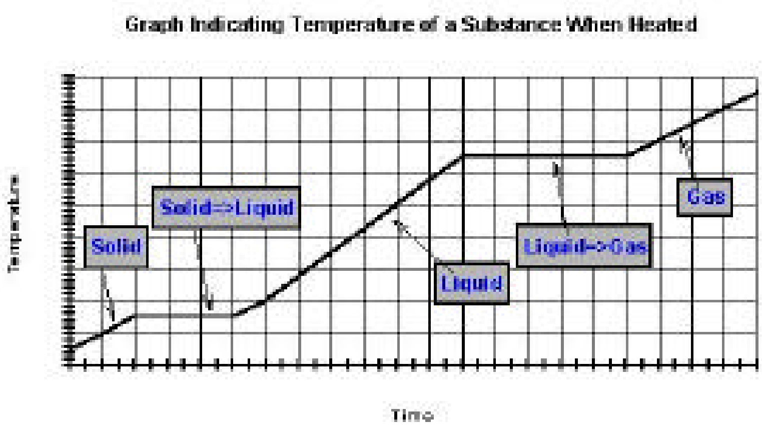
Students design investigations to observe the phase changes of water. Using this information they analyze the energy flow through the global water cycle and begin to understand the importance of the oceans in transferring heat around the globe.

Background knowledge / teacher notes:

When a substance such as water is heated, its temperature will rise at a constant rate. This rate is dependent upon the specific heat of the substance. (The amount of heat, measured in calories, required to raise the temperature of one gram of a substance by one degree Celsius.) However, this is not true during a phase change.

When a substance is going through a phase change (solid to liquid or liquid to gas), the temperature stays constant until the phase change is complete. All the heat that is given to the substance during a phase change is known as latent heat or "hidden" heat. Instead of raising the temperature during a phase change, the heat is used to change the phase of the substance. If a substance is being cooled instead of being heated, the temperature of the substance again does not change during the phase change.

The latent heat of vaporization is 2260 KJ/kg at 100°C. This is the amount of energy that must be added to each kilogram of boiling water to change it to water vapor. Conversely, the latent heat of fusion is the energy needed to change ice to a liquid. To raise the temperature of water from 0°C to 100°C is 419kJ/kg. (Values will vary with atmospheric pressure and apply to sea level.) This a typical graph of a substance going through all three phases of matter:



Credit: University of Michigan.

Available: http://www.eecs.umich.edu/~coalitn/sciedoutreach/funexperiments/quickndirty/latentheat.html

Instructions for Teacher Demonstration.

Activity

Day 1:

1. Draw an indicator line around the top of the bowl (you will fill the bowl with water to this line). If you plan to leave the experiment set up for several days, the indicator line will help you see the amount of evaporation.
2. Spread out the absorbent paper over an area just larger than the size of the aquarium.
3. Fill the bowl with water to the indicator line, and add a drop of food coloring to the water so that it is easier to see the water as it moves through the aquarium. Put the bowl at one end of the paper.
4. Place three thermometers on the paper, one near each end and one in the center. Turn the empty aquarium upside down over the paper. Make sure the aquarium covers the bowl and three thermometers.
5. Shine a bright light down through the glass directly over the bowl of water. Brighter bulbs lead to better results. The light bulb end represents the equator end and the opposite end represents Earth's pole.
6. Leave the light shining over the water bowl overnight.

Day 2:

7. Cover the roof of the aquarium evenly with zip-lock bags of ice. Make sure that the bags are well sealed so that there are no leaks. Wait a few minutes. Add more ice bags if necessary.
8. Check the aquarium every ten minutes. Where do you see water? Is the water moving in the aquarium. Note the water level in the bowl. How much water is in the bowl? Diagram the aquarium and the *condensation* patterns.
9. Record temperatures at each end and in the middle of the aquarium. Note the *evaporation* of water from the bowl, the movement of the water in the aquarium and each thermometer's temperature. Does the temperature *gradient* correlate with the movement of water?

Explanation

What you have observed in your aquarium is a very simple version of Earth's hydrologic cycle. Through the process of *evaporation*, the liquid water became *water vapor*. Water vapor is invisible. As the water vapor cooled at the top of the container, it formed tiny water droplets. This process is called *condensation*, the process of water vapor changing into liquid.

The hydrologic cycle is one mechanism for distributing water and heat on Earth. The oceans play an important role in the cycle. Water evaporates from the ocean and, in some instances, the winds carry the water vapor inland. Eventually, the water vapor cools in the atmosphere and forms tiny water droplets that combine into larger raindrops. Note: This is a very simplified explanation for an extremely complex process.

From JPL. (1998). Visit to an Ocean Planet. “Earth's Hydrologic Cycle.”

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Lesson Description:

ENGAGE	Discussion: 1. What happens to the temperature of water when it's heated? 2. What is the boiling point of water? 3. How do we know when water reaches its boiling point? ***Journal Write:*** Write a hypothesis to predict what happens to the temperature of water as it reaches its boiling point, and afterwards.
EXPLORE	Working in their lab groups, student design an experiment test their hypothesis. Materials: hot plate, Erlenmeyer flask, aluminum foil, thermometer or CBL with temperature probe, distilled water ***Journal Write:*** 1. Design the procedures and data table. 2. After the teacher reviews your procedures begin the experiment. Teacher Note: Caution students to stop heating once the water has completely boiled out. G/T Connection: Using the following information: The latent heat of vaporization is 2260 KJ/kg at 100°C. This is the amount of energy that must be added to each kilogram of boiling water to change it to water vapor. Students calculate the amount of energy needed to vaporize boiling water.
EXPLAIN	***Journal Write***: Graph results and write a short explanation of the graph. In small groups, discuss why the graph levels off. Class discussion: 1. Why did the graph level off? *Phase change is occurring.*

	2. What is taking place during the phase change? *Heat is being absorbed and used to overcome the attraction between the water molecules*. 3. What term best describes this leveling off? *Latent heat*
EXTEND	Discussion: 1. What is the freezing point of water? 2. How do we know when water reaches its freezing point? ***Journal Write:*** Write a hypothesis to predict what happens as the temperature of water as it reaches its freezing point and afterwards. Working in their lab groups, student design an experiment to test their hypothesis. Materials: large beaker 600mL, small Erlenmeyer flask, stirring rod, thermometer, rock salt, ice, distilled water Sample Procedures: 1. Prepare a freezing mixture - a 50/50 mixture of ice cubes and rock salt in the large beaker 2. Place 20 mL of fresh water in the Erlenmeyer flask. 3. Insert the flask into the freezing mixture. The flask must be completely surrounded by the freezing mixture. 4. Insert the thermometer into the flask. 5. Stir the freezing mixture constantly and the water in the flask occasionally. ***Journal Write:*** Design the procedures and data table. <u>G/T Connection:</u> Materials: large beaker 600mL, small Erlenmeyer flask, stirring rod, thermometer, rock salt, ice, salt water

	Design an experiment to determine the effect of salt on the freezing point of water. ***Journal Write:*** 1. What effect did salt have on the freezing point? 2. Why don't the oceans freeze? After the teacher reviews your procedures begin the experiment. ***Journal Write***: 1. Why did the rock salt and ice mixture melt? (Hint: where did the heat come from the melt the ice?) *liquid water inside the flask.* 2. Why did the freshwater freeze? Provide students with a diagram of the Earth's heat budget. (see resources) or other similar diagrams. NASA. Sees. *Surface Heat Budget.* Available: http://see.gsfc.nasa.gov/edu/SEES/ocean/ocean_lectures/sst_lecture/Part_1/index.htm ***Journal Write:*** Refer to the diagram of the Surface Heat Budget as you describe the relationship among latent heat and phase changes to the forces that drive the Earth's heat budget. Adaptive Strategy: Connect latent heat and phase changes to the Earth's hydrologic cycle by performing this laboratory activity as a teacher demonstration. JPL. Classroom Activities. Visit to an Ocean Planet. *Earth's Hydrologic Cycle.* Available: http://topex-www.jpl.nasa.gov/education/activities/ts1ssac2.pdf

	JPL. (1998). Visit to an Ocean Planet. “Earth’s Hydrologic Cycle.” Provide students with a picture of Earth’s hydrologic cycle. Work with them to label condensation, precipitation, evaporation, and transpiration. Discuss whether energy is being absorbed or released during each process.
EVALUATE	***Journal Write:*** Create a systems diagram that relates the different phases of water and identifies where energy is absorbed or released. G/T Connection: Revisit the gas laws and explain how atmospheric pressure might affect the heat of vaporization and the heat of fusion.

Materials per lab group:

- Hot plate
- Thermometer or CBLs and temperature probe
- Aluminum foil: 2 cm x 2cm
- Ice
- Beaker 600 mL
- Erlenmeyer flask, small, medium
- Rock salt
- Stirring rod
- Distilled water
- Salt water
- Water cycle diagram
- Earth’s heat budget diagram

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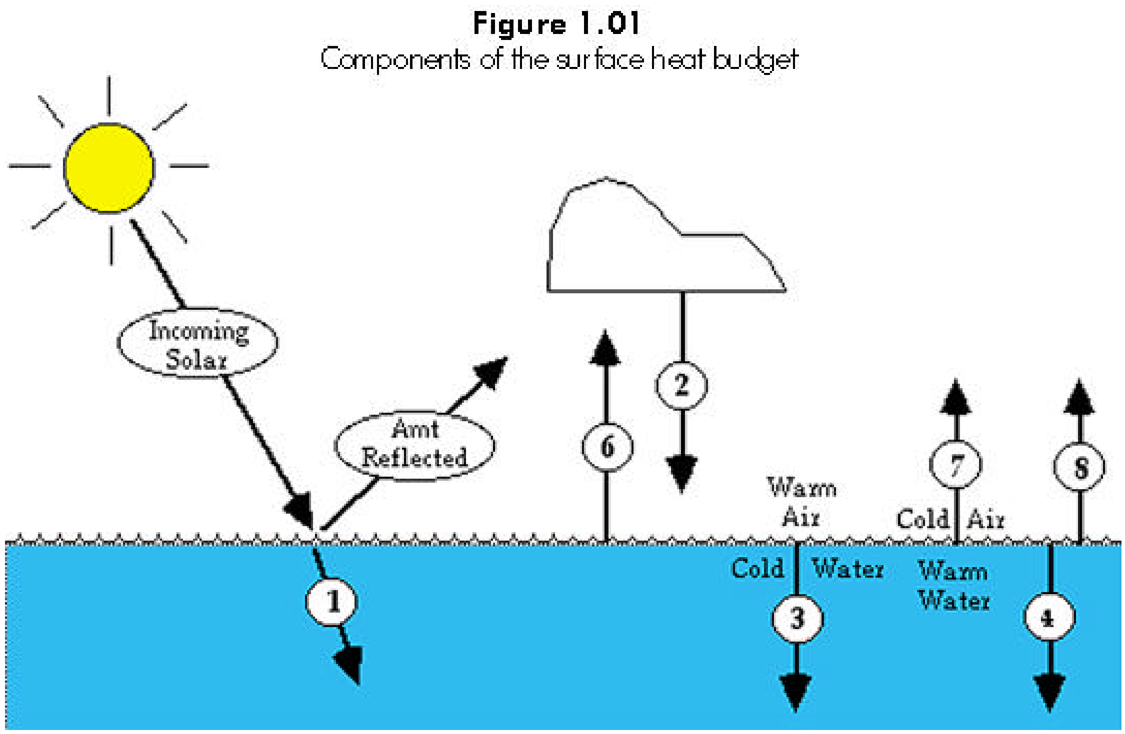

From NASA. Sees. *Surface Heat Budget.*

Available: http://see.gsfc.nasa.gov/edu/SEES/ocean/ocean_lectures/sst_lecture/Part_1/index.htm

Resources:

JPL. Classroom Activities. Visit to an Ocean Planet. *Earth's Hydrologic Cycle.*

Available: http://topex-www.jpl.nasa.gov/education/activities/ts1ssac2.pdf

JPL. (1998). Visit to an Ocean Planet. "Earth's Hydrologic Cycle."

NASA. Sees. *Surface Heat Budget.*

Available: http://see.gsfc.nasa.gov/edu/SEES/ocean/ocean_lectures/sst_lecture/Part_1/index.htm

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Lesson 2: SEA ICE

Estimated Time: Two fifty-minute blocks

Indicators(s) Goal 1: Skills and Processes

1.2.4 The student will test a working hypothesis.

1.4.2 The student will analyze data to make predictions, decisions, or draw conclusions.

1.4.3 The student will use experimental data from various investigators to validate results.

1.4.9 The student will use analyzed data to confirm, modify, or reject an hypothesis.

Indicators(s) Goal 2: Earth-Space Science

2.3.2 The student will explain how global conditions are affected when natural and human-induced change alter the transfer of energy and matter. Assessment limits (at least) – Sea level, glaciers and sea ice, biome location and distribution, emergent and submergent coastlines

Student Outcome(s):

1. The student will be able to determine the effect of sea ice on the atmosphere by conducting a laboratory investigation and analyzing data.
2. The student will be able to correlate the presence of sea ice with ocean circulation patterns by reading a technical passage and viewing a computer simulation.

WHAT DOES THE RESEARCH SAY?

The global temperature has fluctuated within a relatively narrow range, one that has been narrow enough to enable life to survive and evolve for over three billion years. Students come to understand that some of the small temperature fluctuations have produced what we perceive as dramatic effects in the earth system, such as the ice ages and the extinction of entire species. Students explore the regulation of earth's global temperature by the water and carbon cycles. Heating of earth's surface and atmosphere by the sun drives convection within the atmosphere and oceans, producing winds and ocean currents. National Research Council, *National Science Education Standards* (1996).

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Brief Description:

In this lesson, students investigate the effect of sea ice on air temperature and ocean circulation. They will design and conduct a laboratory investigation, and will use computer simulations and satellite data to explore the significance of sea ice.

Background knowledge / teacher notes:

The Arctic plays a prominent role in global environmental change and in our understanding of such change. Because of the extremely fine balance between local geophysical processes--and between these processes and the Arctic biosphere--the Arctic is especially vulnerable to regional or global changes in the environment. This region is characterized by one of the most extreme environments on the planet, with limited sunlight, extreme temperatures, and a short growing season. Sea ice, snow cover, glaciers, tundra, permafrost, boreal (northern) forests, and peatlands are all sensitive to such changes as subtle variations in sunlight, surface temperature, ocean heat transport, air and ocean chemistry, and the presence of particulates in the atmosphere. Historical climatological records are stored in the Greenland Ice Sheet.

The Arctic system can also affect global climate directly through interactions between its atmosphere, ice cover, and ocean, and through feedback processes, whereby changes in geophysical phenomena have direct effects on others. For example, feedback among ice extent, snow cover, surface Albedo, and the global heat budget are crucial to determining the global climate. Indeed, most computer-based global climate models predict amplification of the global greenhouse effect at high northern latitudes with increasing levels of greenhouse gases (such as carbon dioxide and methane) in the atmosphere. Such observations suggest that interactions between Arctic and global processes can have important implications for our society. Some of these processes include:

- The hydrological cycle of the Arctic Basin, which links precipitation, river runoff, sea ice, and ocean circulation as a single system. This system exerts strong control on deep-water formation and the circulation of the Atlantic Ocean. In turn, changes in the circulation of the Atlantic Ocean affect global climate, including high-latitude precipitation and the exchange of carbon dioxide between the atmosphere and ocean, thereby closing a feedback loop of potentially global significance.

- Reductions in the amount of Arctic sea ice and snow cover, which reduce the reflectivity of the land or ocean surface and allow more solar energy to be absorbed, leading to increased heat flow from the surface to the atmosphere. The resulting rise in air temperature may bring about a further loss of snow and sea ice, completing a positive feedback loop that affects the global distribution of winds, clouds, and precipitation. However, changes in snow and ice cover may affect the amount of evaporation and cloud cover, thus introducing another feedback to the overall system, one that might reduce warming.
- Global warming, which may cause significant changes in Arctic land ice and glacier extent, thereby affecting sea level.
- The organization of Arctic marine life into complex food webs that are strongly affected by the amount of sea ice, the availability of certain nutrients, and water density. Changes in these factors due to global warming effects on the local environment may induce large changes in Arctic marine ecosystems. This, in turn, may affect the way some essential nutrients (such as carbon, nitrogen, and phosphorous) are distributed, with consequences far beyond the Arctic.
- The limits on growth of Arctic terrestrial life by a short growing season, low temperatures, and low rates of nutrient cycling. Warmer temperatures will change these factors and cause changes in the composition of plant communities and, ultimately, the animals that eat them. This, in turn, may affect the harvest of animals and plants by humans.
- The sources and sinks (storage places) of global carbon dioxide and methane in Arctic soils and peatlands. The processes that control the release or uptake of these gases involve strong feedbacks from plant and animal communities, which respond sensitively to local changes in soil moisture and temperature.
- The transport of industrial air pollution in the Northern Hemisphere by atmospheric circulation to the Arctic, where it appears as "Arctic haze." Although its concentration is low this largely sooty, acidic material induces warming in the troposphere by absorbing

sunlight, which can affect the climate over large areas. Alternatively, sulfur dioxide emissions from industrialized regions in the Northern Hemisphere are converted to sulfuric acid in the atmosphere, and may shield the Earth from incoming solar radiation, thereby cooling our environment.

Clearly, Arctic phenomena and their interactions are complex and must be understood not only for their own sake, but to help us understand geophysical phenomena on a global scale, as well. (from CIESIN. (1996). *Sea Ice in the Polar Regions and The Arctic Observatory*. "Teacher's Guide to the Arctic Observatory." CD-ROM)

Students probably know there are vast ice sheets at Earth's poles. However, they may not be aware of the sheer size of these ice sheets, or that they are covered by ice undergoes large seasonal fluctuations. The graphics and narration on the CD-ROM, *Sea Ice in the Polar Regions and The Arctic Observatory*, do a great job of illustrating the roles of sea ice, its seasonal fluctuations, and the importance of remote sensing in the study of sea ice.

Teacher note: If you do not have the CD-ROM *Sea Ice in the Polar Regions and The Arctic Observatory*, both programs may be downloaded at Universities Space Research Association. *Earth Systems Science and Global Change.*
Available: http://www.usra.edu/esse/learnmod.html

Lesson Description:

ENGAGE	Technology Connection Have the students view the introduction to "Sea Ice in the Polar Regions" on the CD-ROM, *Sea Ice in the Polar Regions and The Arctic Observatory*. Or from the website Universities Space Research Association. *Earth Systems Science and Global Change.* Available: http://www.usra.edu/esse/learnmod.html Discussion: 1. Predict how changes in the amount of sea ice affect air temperature.

	2. How can we simulate this phenomenon?
EXPLORE	Have the students perform the following laboratory investigation. 1. Using a ring stand and clamp suspend a thermometer or temperature probe over a beaker full of ice. 2. Place the lamp so that it melts the ice, but does not shine directly on the thermometer. 3. Monitor the temperature of the air above the beaker as the ice melts. Materials: ice, ring stand, beaker, temperature probe or thermometer, heat lamp ***Journal Write:*** 1. Create a hypothesis about how the air temperature over the beaker will change as the ice melts. 2. Write a procedure for your laboratory investigation. 3. Design a data table for your investigation. <u>Adaptive Strategy</u>: Help students decide where to place the thermometer, and how often they should take temperature readings. Model designing a data table. Have the students conduct their experiments.
EXPLAIN	***Journal Write:*** 1. How does the presence of ice affect the temperature of the surrounding air? Use evidence from your data to support your answer. 2. Based on your results, predict how seasonal changes in the amount of sea ice affect the air temperature at Earth's poles.
EXTEND	We have seen how sea ice influences atmospheric temperature. How does the amount of sea ice affect the surrounding ocean water? <u>Technology Connection</u> On the CD-ROM, *Sea Ice in the Polar Regions and The Arctic Observatory*, view all the subsections of "Impact of Sea Ice" found in the *Sea Ice in the Polar Regions* section.

	Or from the website Universities Space Research Association. *Earth Systems Science and Global Change.* Available: http://www.usra.edu/esse/learnmod.html ***Journal Write:*** Create a systems diagram illustrating the impact of sea ice on the atmosphere and surrounding ocean. Visit "The Arctic Observatory" found on *Sea Ice in the Polar Regions and The Arctic Observatory*. Select "Observatory" from the main menu. The dual maps allow you to compare different features of the Arctic, including monthly percentages of ice cover and surface temperatures from January, 1985 through June, 1990. Adaptive Strategy: Help the students locate the edges of the ice flows. Discussion: 1. Describe the relationship between surface temperature and the amount of sea ice present in the Arctic. *As temperature increases, the amount of sea ice decreases.* 2. Predict the relative amounts of sea ice found in the Arctic and Antarctic during any given month. *When the northern hemisphere experiences summer, it is winter in the southern hemisphere. So, when the amount of sea ice is at a minimum in the Arctic, it should be at a maximum in the Antarctic.* How can we test this prediction? Return to "Sea Ice in the Polar Regions" and select "Sea Ice Distributions." CIESIN. (1996). *Sea Ice in the Polar Regions and The Arctic Observatory*. "Sea Ice Distributions." CD-ROM. Or from the website Universities Space Research Association. *Earth Systems Science and Global Change.* Available: http://www.usra.edu/esse/learnmod.html

	Journal Write: Based on the computer simulation, compare the North and South Poles in terms of seasonal sea ice coverage. G/T Connection: Based on the computer simulation, what can you conclude about the total amount of global sea ice at any given time of year? INTEREST CENTER: NASA JPL. *Everything You Ever Wanted to Know About ICE But Were Afraid to Ask.* Available: http://southport.jpl.nasa.gov/polar/iceinfo.html G/T/ Technology Connection: For a more in-depth look at climate research into the roles of sea ice, visit Bjerknes Research and Training. *Coupled Ocean-Ice Processes and Modeling.* Available: http://www.bjerknes.uib.no/Research/rg2.html This site links to a climate model at Bjerknes Research and Training. *The Bergen Climate Model.* Available: http://www.bjerknes.uib.no/Research/BCMmovie.html ***Journal Write:*** How do models help scientists investigate sea ice and its impact on the atmosphere, the ocean, and climate?
EVALUATE	***Journal Write:*** How do seasonal changes in the amount of sea ice affect atmospheric temperatures, and ocean circulation and temperature? Include evidence from your laboratory data, computer simulations, and your systems diagram.

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Materials per lab group:

- Ice
- Ring stand with clamp
- Beaker
- Temperature probe or thermometer
- Heat lamp

Resources:

Bjerknes Research and Training. *The Bergen Climate Model.* Available: http://www.bjerknes.uib.no/Research/BCMmovie.html

Bjerknes Research and Training. *Coupled Ocean-Ice Processes and Modeling.* Available: http://www.bjerknes.uib.no/Research/rg2.html

Universities Space Research Association. *Earth Systems Science and Global Change.* Available: http://www.usra.edu/esse/learnmod.html

CIESIN. (1996). *Sea Ice in the Polar Regions and The Arctic Observatory*. "Impacts of Sea Ice." CD-ROM

INTEREST CENTER:

NASA JPL. *Everything You Ever Wanted to Know About ICE But Were Afraid to Ask.* Available: http://southport.jpl.nasa.gov/polar/iceinfo.html

Earth/Space Systems Science
Unit III: The Hydrosphere

Lesson 3: DAILY SEA-LAND BREEZES AND CLIMATE

Estimated Time: One fifty-minute block

Indicator(s) Core learning Goal 1:

1.1.2 The student will modify or affirm scientific ideas according to accumulated evidence.

1.2.2 The student will pose meaningful, answerable scientific questions.

1.2.3 The student will formulate a working hypothesis.

1.2.4 The student will test a working hypothesis.

1.4.2 The student will analyze data to make predictions, decisions, or draw conclusions.

1.4.3 The student will use experimental data from various investigators to validate results.

1.4.8 The student will use models and computer simulations to extend his/her understanding of scientific concepts.

Indicator(s): Core Learning Goal 2:

2.1.2 The student will describe the purpose and advantage of current tools, delivery systems and techniques used to study the atmosphere, land and water on Earth.
Assessment limits (at least) –Delivery systems (satellite-based, ground-based), Techniques (imaging, Geographic Information System, Global Positioning System, spectroscopy, Doppler).

2.3.1 The student will describe how energy and matter transfer affect Earth systems.
Assessment limits (at least) - Oceanic circulation (density differences, daily and seasonal land/sea breezes, Coriolis effect).

2.3.2 The student will explain how global conditions are affected when natural and human-induced change alter the transfer of energy and matter. Assessment limits: Climate type and distribution (temperature and precipitation.)

Student Outcome(s):

1. The student will be able to explain the formation of sea-land breezes by analyzing daily weather information and satellite images.
2. The student will be able describe the influence oceans have on climate by reading a technical passage and comparing coastal and inland climates.

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WHAT DOES THE RESEARCH SAY?

Heating of earth's surface and atmosphere by the sun drives convection within the atmosphere and oceans, producing winds and ocean currents. National Research Council, *National Science Education Standards* (1996).

Brief Description:

This lesson builds on the concepts of global winds, developed in Unit II. It helps set the stage as students start to think about interactions between the atmosphere and the hydrosphere and the ever-present role of energy in earth systems. In this lesson, students apply their knowledge of air pressure and analyze the development of sea-land breezes and determine the moderating influence oceans have on coastal climates.

Background knowledge / teacher notes:

Sea breezes are often experienced during summertime beach visits as strong steady winds blow from the water to the land around 3:00 P.M. Uneven heating of the land and water during the day result as the water has an increased heat capacity and thermal conductivity. Land warms faster than water and heats adjacent air by convection. That air rises, heats the air above it by convection, and a pressure gradient column is created, resulting in thermal circulation. The water in the adjacent ocean releases heat more slowly, causing a difference in air pressure. The cooler air over the water forms an area of higher pressure. This results in a pressure gradient towards the land, i.e., a sea breeze is formed. Land air rises and the cooler ocean air rushes in to take its place. Since the air over the water is cooler, it can cool the land closest to the water. (This is why land closest to the water is cooler than areas further inland.) At night the process reverses as the air over the land cools quickly and the air over the water retains most of its heat. This causes the pressure gradient to reverse, creating a land breeze.

For more detailed background information see:

University of Wisconsin. *Sea and land breezes.*

Available: http://cimss.ssec.wisc.edu/wxwise/seabrz.html

Danish Wind Industry Association. *Local Winds: Sea Breezes.*

Available: http://www.windpower.dk/tour/wres/localwin.htm

Lesson Description:

ENGAGE	Technology Connection: Download air temperatures for Ocean City, MD. USA Today Climate. *Ocean City, Maryland.* Available: http://www.usatoday.com/weather/climate/usa/md/woceanci.htm Download the water temperatures for Ocean City, MD USA Today Weather. *Water Temperature Guide.* Available: http://www.usatoday.com/weather/marine/wh2omatl.htm Teacher Note: This information is also available in most newspapers. Do a Think-Pair-Share Examine the water temperatures and air temperatures for each month from June through October. 1. How has the air temperature changed over the time period? 2. How has the water temperature changed over the time period? 3. Compare the changes in air temperatures and water temperatures. *Air temperatures rise and fall faster than water.* Discussion: What do these temperature changes indicate about the heat capacity of land vs. water? *Water has a high heat capacity. It takes longer to heat up and cool down.* Adaptive Strategy: Show students a map illustrating the heat capacity of land and water. (see resources). Bigelow Laboratory for Ocean Sciences. *Virtual Vacation. Heat Capacity.* Available: http://www.bigelow.org/virtual/heat_cap.jpg
EXPLORE	***Journal Write:*** Predict the wind patterns over coastal areas.

	Technology Connection: University of California, Los Angeles, Department of Atmospheric Sciences. *Simulation of the Los Angeles sea/land breeze.* Available: http://www.atmos.ucla.edu/~fovell/ASother/mm5/LA_seabreeze.html View the diagrams of the Ground/Sea surface temperature and near surface wind vectors. ***Journal Write:*** 1. Make a graphic organizer. 2. Record the wind directions and the temperature of the land and water over the course of 24 hours.
EXPLAIN	***Journal Write:*** 1. Describe relationship between coastal land and water temperatures and the direction of the coastal winds. 2. Why do coastal areas experience daily sea breezes? Adaptive Strategy: Have students read to be informed about sea breezes Atmospheric Environment. *Sea Breeze.* Available: http://www.doc.mmu.ac.uk/aric/eae/Weather/Older/Sea_Breeze.html Adaptive Strategy: View an animation of a sea breeze. JPL (1998) Visit to an Ocean Planet. CD-ROM "Offshore breezes." At the map click on Climate then Scale and Structure and finally movies. Technology Connection: View graphic of sea breeze and land breeze. Atmospheric Environment. *Sea Breeze.* Available: http://www.doc.mmu.ac.uk/aric/eae/Weather/Older/Sea_Breeze.html Click on Sea Breeze and Land Breeze buttons located below the reading. What does this type of air circulation represent? *Convection current or gyre*
EXTEND	Read to be informed about the interaction between the ocean and

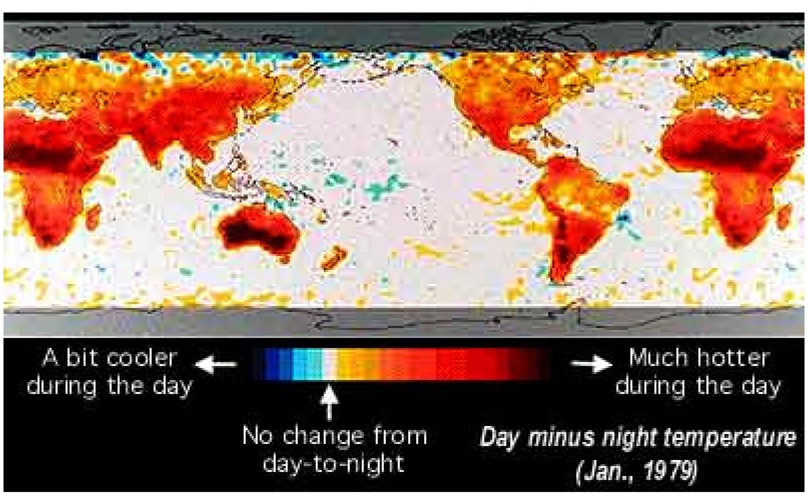
	atmosphere. (see resources) Earth Observatory. NASA. *Ocean and Climate: Physical coupling with the atmosphere.* Available: http://earthobservatory.nasa.gov/Library/OceanClimate/ocean-atmos_phys.html Create a graphic organizer to record information about the oceanic and atmospheric interactions. Working in pairs, examine the graph "Outdoor Temperature vs. Time." (see resources.) The Outdoor Temperature vs. Time graph shows the temperatures of a coastal site and inland site over a week. The white dots represent the inland site while the yellow line represents coastal site. ***Journal Write:*** 1. Compare the inland and coastal temperatures. Use evidence from the graph to support your answer. *The coastal area has a moderate changes in temperature while the inland area experiences more extreme temperatures.* 2. Write a hypothesis to explain these differences. *Sea-land Breeze and the moderating influence of the ocean on climate.* Working in pairs, examine the graph "Outdoor Temperature, Wind Direction vs. Time." (See resources) ***Journal Write:*** 1. What is the relationship between the air temperatures and the wind direction? *"The daytime wind is generally coming from the West (off the water). This keeps the shoreline much cooler than the air further from the beach. At night, the wind shifts to a more Northeasterly direction that draws the warmer land-air towards the shoreline and moderates*

	the overnight low temperature." AWS Convergent Technologies. Cool AirWatch Data Archives. *Sea Breeze Hits Cunha Middle School and California Coast.* Available: http://www.aws.com/greatesthits/default.asp?CID=19 2. Did the data support your hypothesis? 3. Use evidence from the graph to support your conclusion. *The same sea breeze that keeps the shore up to 40 degrees cooler during the day, keeps the shore a little warmer at night.* Read to be informed about how technology allows us to accurately monitor sea-land breezes. Rutgers University Coastal Ocean Observations. *How are sea breezes detected and analyzed?* Available: http://marine.rutgers.edu/cool/seabreeze/seabreeze.htm Teacher Note: Students should stop reading after the CODAR section. ***Journal Write:*** 1. What technology is used to detect and analyze sea/land breezes? 2. Describe the relationship between sea breezes and ocean currents? "As a sea breeze develops and the winds over the ocean change directions, the current direction changes accordingly. The ocean currents become light and variable, and then quickly shift to an onshore direction. As the winds behind the sea breeze front change, the ocean currents change but with a lag time of up to 1 or 2 hours. As the sea breeze circulation breaks apart or reverses, the currents should switch back to an offshore direction.' Rutgers University Coastal Ocean Observations. *How are* sea breezes *detected and analyzed?* Available: http://marine.rutgers.edu/cool/seabreeze/seabreeze.htm G/T/ Technical Connection:

	Find out how space technology provides information sea breezes NASA GSFC. *Local Winds - Oceanography from the Space Shuttle.* Available: http://daac.gsfc.nasa.gov/CAMPAIGN_DOCS/OCDST/shuttle_oceanography_web/oss_48.html Print the pictures of Sumba, Indonesia and Baja California. ***Journal Write:*** 1. Outline the location of the sea breezes and draw the direction of the wind. 2. Predict how sea breezes influence local weather patterns.
EVALUATE	***Journal Write:*** 1. How does the ocean affect coastal climates? Cite evidence from the reading and graphics to support your answer. View the animation of sea breeze Texas A & M. Local weather: *Sea Breeze Animation.* Available: http://www.met.tamu.edu/class/Metr151/tut/seabr/sea18.html 2. Using your knowledge of sea breezes, write a caption explaining the animation.

Materials:

- Outdoor Temperature vs. Time graph
- Outdoor Temperature, Wind Direction vs. Time graph



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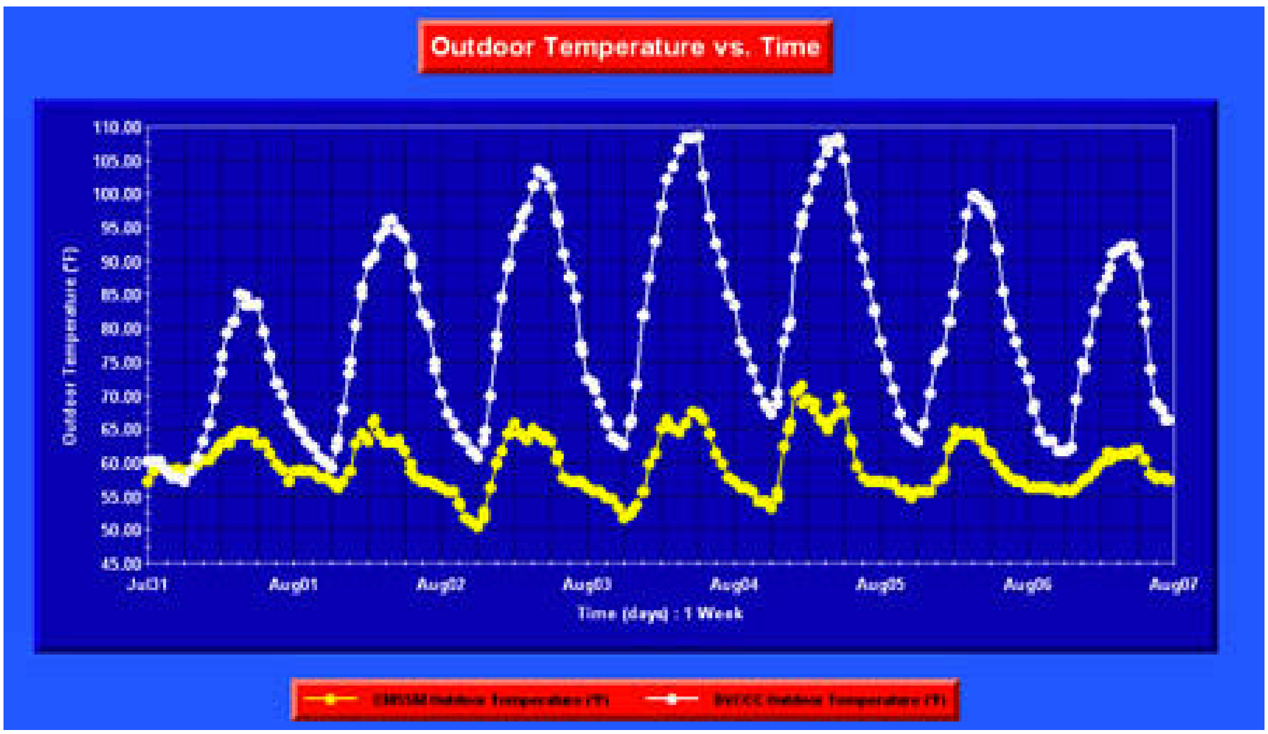
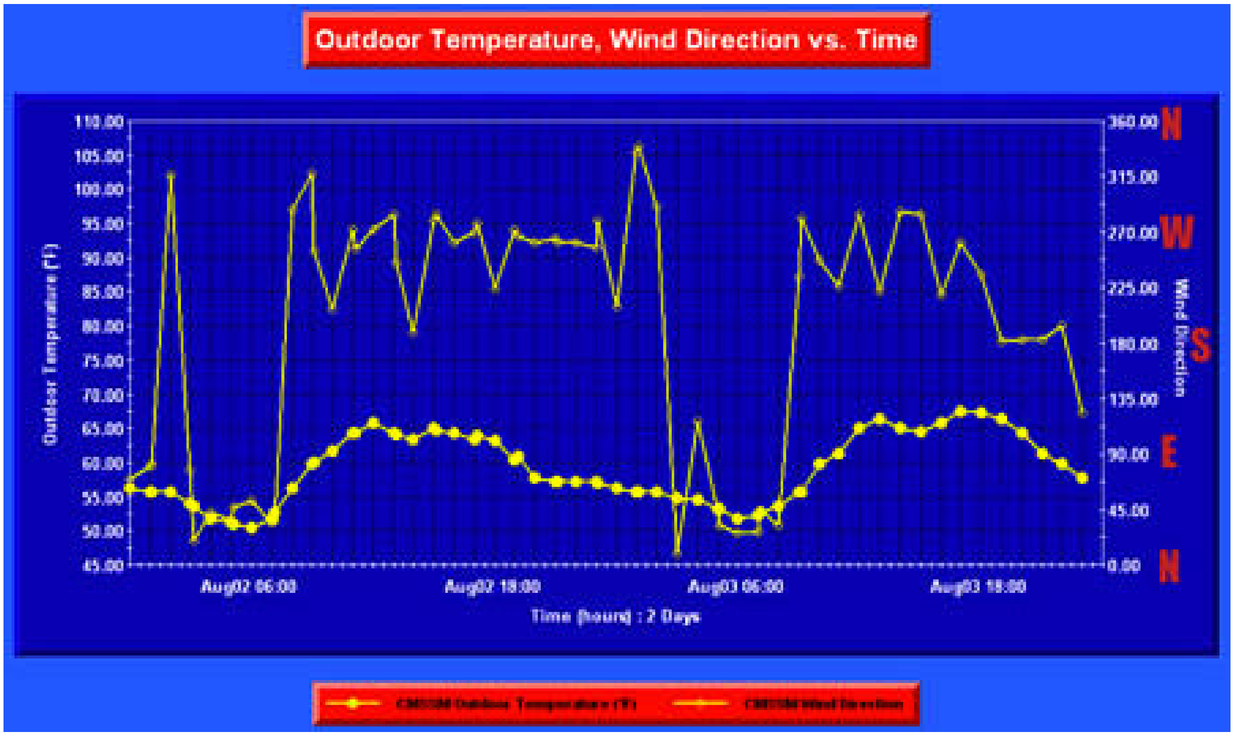
The map shows the difference in heat capacities of Earth's ocean water and its continental rocks. Areas that show very little difference in temperature from night-to-day are colored white. Areas that show very large differences in temperature from night-to-day are shown as red. From Bigelow Laboratory for Ocean Sciences. *Virtual Vacationland. Sea Surface Temperatures.* Available: http://www.bigelow.org/virtual/heat_cap.jpg



The Outdoor Temperature vs. Time graph shows the temperatures of a coastal site and inland site over a week. The white dots represent the inland site while the yellow line represents coastal site.



The graph shows the wind direction and temperature over a two-day period at the coastal site. The yellow line shows wind direction (measured in degrees: 0 and 360 = North, 90 = East, 180 = South, 270 = West) as reflected in the right Y-axis. The yellow dotted line is temperature shown by the scale on the left Y-axis.

From AWS Convergent Technologies. Cool AirWatch Data Archives. *Sea Breeze Hits Cunha Middle School and California Coast.*

Available: http://www.aws.com/greatesthits/default.asp?CID=19

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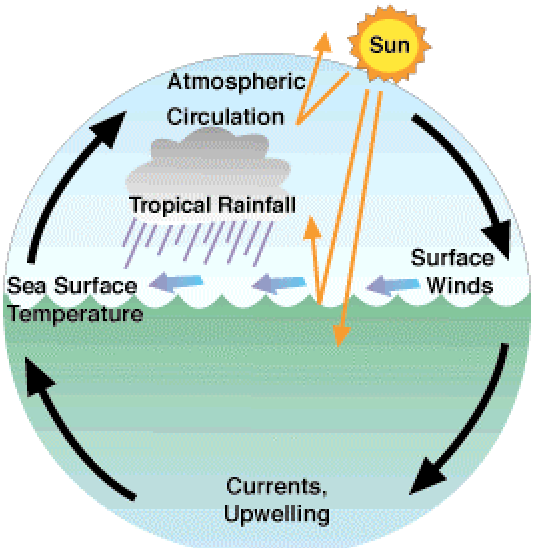
Oceans and Climate

Physical coupling of the ocean with the atmosphere



The ocean couples with the atmosphere in two main ways. The first way is physically, through the exchange of heat, water, and momentum. Covering more than 70 percent of the Earth's surface and containing about 97 percent of its surface water, the ocean stores vast amounts of energy in the form of heat. The ocean receives most of its heat along the equator, where incoming solar radiation is about double that received at the poles. Hence, sea surfaces are much warmer along the equator than at the poles.

Ocean and atmosphere move because they are fluid. The speed and direction of air and sea currents are determined primarily by air temperature gradients. As heat rises and eventually escapes the ocean to warm the overlying atmosphere, it creates air temperature gradients and, consequently, winds. In turn, winds push against the sea surface and drive ocean current patterns.

Over time, a complex system of currents was established whereby the ocean transports a tremendous amount of heat toward the poles. Because heat escapes more readily into a cold atmosphere than a warm one, the northward flow of ocean and air currents is enhanced by the flow of heat escaping into the atmosphere and, ultimately, into outer space.

The ocean has a high temperature and momentum "inertia," or resistance to change. Relative to the atmosphere, it has a very slow circulation system, so changes in its systems generally occur over much longer timescales than in the atmosphere, where storms can form and dissipate in a single day. The ocean changes over periods from months to years to decades, whereas the atmosphere changes over periods of minutes to hours to days.

Earth Observatory. NASA. *Ocean and Climate: Physical coupling with the atmosphere.* Available: http://earthobservatory.nasa.gov/Library/OceanClimate/ocean-atmos_phys.html

Resources:

Rutgers University Coastal Ocean Observations. *How are* sea breezes *detected and analyzed?*
Available: http://marine.rutgers.edu/cool/seabreeze/seabreeze.htm

JPL (1998) Visit to an Ocean Planet. CD-ROM "Offshore breezes."

Danish Wind Industry Association. *Local Winds: Sea Breezes*.
Available: http://www.windpower.dk/tour/wres/localwin.htm

Earth Observatory. NASA. *Ocean and Climate: Physical coupling with the atmosphere.*
Available: http://earthobservatory.nasa.gov/Library/OceanClimate/ocean-atmos_phys.html

USA Today Climate. *Ocean City, Maryland.*
Available: http://www.usatoday.com/weather/climate/usa/md/woceanci.htm

NASA GSFC. *Local Winds - Oceanography from the Space Shuttle.*
Available:
http://daac.gsfc.nasa.gov/CAMPAIGN_DOCS/OCDST/shuttle_oceanography_web/oss_48.html

University of Wisconsin. *Sea and land breezes.*
Available: http://cimss.ssec.wisc.edu/wxwise/seabrz.html

Atmospheric Environment. *Sea Breeze.*
Available: http://www.doc.mmu.ac.uk/aric/eae/Weather/Older/Sea_Breeze.html

Texas A & M. Local weather: *Sea Breeze Animation.*
Available: http://www.met.tamu.edu/class/Metr151/tut/seabr/sea18.html

AWS Convergent Technologies. Cool AirWatch Data Archives. *Sea Breeze Hits Cunha Middle School and California Coast.*
Available: http://www.aws.com/greatesthits/default.asp?CID=19

Bigelow Laboratory for Ocean Sciences. *Virtual Vacationland. Sea Surface Temperatures.*
Available: http://www.bigelow.org/virtual/heat_cap.jpg

University of California, Los Angeles, Department of Atmospheric Sciences. *Simulation of the Los Angeles sea/land breeze.*
Available: http://www.atmos.ucla.edu/~fovell/ASother/mm5/LA_seabreeze.html

USA Today Weather. *Water Temperature Guide.*
Available: http://www.usatoday.com/weather/marine/wh2omatl.htm

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Lesson 4: MONSOONS

Estimated Time: One fifty-minute block

Indicator(s) Core Learning Goal 1:

1.1.1 The student will recognize that real problems have more than one solution and decisions to accept one solution over another are made on the basis of many issues.

1.1.2 The student will modify or affirm scientific ideas according to accumulated evidence.

1.1.3 The student will critique arguments that are based on faulty, misleading data or on the incomplete use of numbers.

1.4.2 The student will analyze data to make predictions, decisions, or draw conclusions.

1.5.4 The student will use tables, graphs, and displays to support arguments and claims in both written and oral communications.

1.5.8 The student will describe similarities and differences when explaining concepts and/or principles.

1.5.9 The student will communicate conclusions derived through a synthesis of ideas.

Indicator(s) Core Learning Goal 2

2.3.1 The student will describe how energy and matter transfer affect Earth systems. Assessment limits: Oceanic circulation (density differences, daily and seasonal land/sea breezes, Coriolis effect.)

Student Outcome(s):

1. The student will be able to identify the characteristics of a monsoon by analyzing satellite data.
2. The student will be able compare monsoon and sea breezes by completing a graphic organizer and writing a journal entry.

WHAT DOES THE RESEARCH SAY?

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Heating of earth's surface and atmosphere by the sun drives convection within the atmosphere and oceans, producing winds and ocean currents. National Research Council, *National Science Education Standards* (1996).

Brief Description:

In this lesson, students discern the characteristics of monsoons. After analyzing the causes and effects of monsoons, they compare a seasonal event, the monsoon, to a daily event, the sea-land breeze.

Background knowledge / teacher notes:

It is often confusing to students to differentiate among global wind currents, regional climate events (e.g. monsoons), and local weather events (sea and land breezes). While global winds effect climatic changes and play a vital role in ocean circulation, regional and local winds or breezes affect a much smaller portion of the globe respectively. Climate, as derived from the interaction between hydrosphere and atmosphere, is addressed in several other lessons in this curriculum.

Monsoons are seasonal events that affect areas when winds change direction over the Indian Ocean. From April to October southwestern warm winds carry moisture from the Indian Ocean primarily to Arabia, Asian countries, northern Australia, and India. This pattern reverses from November to March when northeastern winds carry high humidity cooler dry weather to those areas. Agriculture is highly dependent upon the moist monsoon months. These events are seasonal, but affect only a portion of the Earth.

Lesson Description:

ENGAGE	<u>Technology Connection</u>: View the news footage of a monsoon. Arizona Star Net. *Monsoon Montage.* Available: http://www.azstarnet.com/monsoon/videoclips.html Discussion: What are the characteristics or effects of a monsoon?

	Technology Connection: Have students analyze the Monsoon animation. NASA. *The Asian Monsoon from the GEOS-1 Multiyear Assimilation.* Available: http://dao.gsfc.nasa.gov/experiments/assim54A/sample_results/monsoon.html To view the animation, click on the 2D monsoon animation located under the graphic.
EXPLORE	Teacher Note: Prior to viewing point out the arrows representing wind direction and the color scale representing amounts of precipitation. Do a Think-Pair-Share 1. Describe the relationship between winds and precipitation. 2. Where in the world does this phenomenon take place? 3. Is this a seasonal phenomenon? Why? *By viewing the months at the bottom students can describe that monsoons occur in the Spring and Summer months.* Adaptive Strategy: Have students work in pairs at a computer. Encourage them to move through the video step-by-step so they can easily see the wind and precipitation patterns each month. Read to be informed about monsoons, their causes and effects. Forces of Nature 2000. *Monsoons.* Available: http://library.thinkquest.org/C003603/english/monsoons/index.shtml or The American Forum for Global Education. *What is a monsoon?* Available: http://www.globaled.org/nyworld/materials/india/waterakey1.html

	Or other similar text passages. Create a graphic organizer to record information about monsoons. ***Journal Write:*** · Describe the causes and effects of a monsoon. The American Forum for Global Education. *Map Study 1: The Path of the Monsoon.* Available: http://www.globaled.org/nyworld/materials/india/mapMonsoon.html ***Journal Write:*** · Examine the map of the monsoon. Write a caption for the map describing the path of the monsoon.
EXPLAIN	In small groups discuss the following questions. 1. How are monsoons similar to sea-land breezes? 2. How are they different? Adaptive Strategy: Suggest that students review the information on sea-land breezes in their journal. Provide the following hints to focus the discussion: location, when do they occur, causes and effects and the amount of energy involved. ***Journal Write:*** · Using a graphic organizer compare sea-land breezes to monsoons.
EXTEND	Technical Connection: What is the forecast for monsoons this year? Monsoon on line. D.B. Stephenson, K. Rupa Kumar and E. Black. *Monsoons.* Available: http://www.tropmet.res.in/~kolli/MOL/Monsoon/frameindex.html#current_monsoon Directions: 1. View the “Current Monsoon” table.

2. In the table, click on Forecast.

Journal Write:

3. Examine the Seasonal Forecast map. Describe the precipitation forecast for Asia. Use data from the graph to support your answer.
4. Use the back button to return to the "Current Monsoon" table.
5. In the table, click on "Cumulative Seasonal Rainfall."

Journal Write:

6. How does the actual amount of precipitation compare to the forecast? Use evidence from the graphs to support your answer. Return to the table. Check on the actual progress of the monsoon. Below the table, click on Progress of the Monsoon and then Current Satellite image.

G/T Connection:

Scroll further down the page and locate the "Recent Monsoon" table. Choose a past monsoon and examine the data.

Journal Write:

How does that monsoon compare to this year's monsoon? Cite evidence from the graphics in your answer.

Discussion:

1. Why is a forecasting monsoon so difficult?
2. How can information sometimes lead to an incorrect forecast?

INTEREST CENTER

How are humans affected by monsoons?

Monsoon on line. D.B. Stephenson, K. Rupa Kumar and E. Black. *Monsoons.*

Available:
http://www.tropmet.res.in/~kolli/MOL/Monsoon/frameindex.html#current_monsoon

	Click on the "News" in either of the tables for news articles on the effects of monsoons.
EVALUATE	***Journal Write:*** Using your graphic organizer, write a paragraph comparing monsoon and sea breezes. Be sure to include the location, amount of energy involved, causes and effects. Cite evidence from the satellite data in your answer.

What is the forecast for monsoons this year?

Monsoon on line. D.B. Stephenson, K. Rupa Kumar and E. Black. *Monsoons*.

Available:

http://www.tropmet.res.in/~kolli/MOL/Monsoon/frameindex.html#current_monsoon

Directions:

1. View the "Current Monsoon" table.
2. In the table, click on Forecast.

Journal Write:

3. Examine the Seasonal Forecast map. Describe the precipitation forecast for Asia. Use data from the graph to support your answer.
4. Use the back button to return to the "Current Monsoon" table.
5. In the table, click on "Cumulative Seasonal Rainfall."

Journal Write:

6. How does the actual amount of precipitation compare to the forecast?
7. Use evidence from the graphs to support your answer.
8. Return to the table.
9. Check on the actual progress of the monsoon. Below the table, click on Progress of the Monsoon and then Current Satellite image.

Resources:

NASA. *The Asian Monsoon from the GEOS-1 Multiyear Assimilation.*
Available: http://dao.gsfc.nasa.gov/experiments/assim54A/sample_results/monsoon.html

The American Forum for Global Education. *Map Study 1: The Path of the Monsoon.*
Available: http://www.globaled.org/nyworld/materials/india/mapMonsoon.html

Forces of Nature 2000. *Monsoons.*
Available: http://library.thinkquest.org/C003603/english/monsoons/index.shtml

Monsoon on line. D.B. Stephenson, K. Rupa Kumar and E. Black. *Monsoons.*
Available: http://www.tropmet.res.in/~kolli/MOL/Monsoon/frameindex.html#current_monsoon

Arizona Star Net. *Monsoon Montage.*
Available: http://www.azstarnet.com/monsoon/videoclips.html

The American Forum for Global Education. *What is a monsoon?*
Available: http://www.globaled.org/nyworld/materials/india/waterakey1.html

Earth/Space Systems Science
Unit III: The Hydrosphere

Lesson 5: WIND-DRIVEN CIRCULATION

Estimated Time: Two fifty-minute blocks

Indicator(s) Core Learning Goal 1:

1.2.7 The student will use relationships discovered in the lab to explain phenomena observed outside the laboratory.

1.5.5 The student will create and/or interpret graphics (scale drawings, photographs, digital images, field of view, etc.).

1.5.8 The student will describe similarities and differences when explaining concepts and/or principles.

Indicator(s) Core Learning Goal 2

2.3.1 The student will describe how energy and matter transfer affect Earth systems. Assessment limits: Oceanic circulation (density differences, daily and seasonal land/sea breezes, Coriolis effect.)

Student Outcome(s):

1. The student will be able to explain the impact of global winds and the Coriolis effect on ocean circulation.
2. The student will be able to predict the location of surface currents by analyzing global wind patterns.

WHAT DOES THE RESEARCH SAY?

Heating of earth's surface and atmosphere by the sun drives convection within the atmosphere and oceans, producing winds and ocean currents. National Research Council, *National Science Education Standards* (1996).

Transfer of heat energy at the boundaries between the atmosphere, the land masses, and the oceans results in layers of different temperatures and densities in both the ocean and atmosphere. The action of gravitational force on regions of different densities causes them to rise or fall—and such circulation, influenced by the rotation of the earth, produces winds and ocean currents.

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AAAS, *Benchmarks for Science Literacy* (1993).

Brief Description:

This lesson builds on the concepts of global winds and Coriolis effect, presented during the atmosphere unit. It sets the stage as students start thinking about interactions between the atmosphere and the hydrosphere and the ever-present role of energy in earth systems. Students construct first-hand knowledge of wind-driven currents by conducting a simulation. They then use that knowledge to develop a graphic of global wind patterns.

Background knowledge / teacher notes:

Winds from the atmosphere are the force behind surface ocean currents. Currents are due to the force of the winds, the Coriolis effect, and the landmasses that block current motions. When a wind blows across the surface of the ocean, energy is transferred from the wind to the sea surface. Winds blow across the surface of the water and drag the water along the surface. This energy generates surface waves and currents. The direction of the currents is affected by the rotation or spinning of the Earth in the Coriolis effect. Global winds combine with the Coriolis effect and shoreline boundaries to drive surface currents in circular patterns called gyres. The currents exhibit the pattern of curving to the right (clockwise) in the Northern Hemisphere and to the left (counterclockwise) in the Southern Hemisphere.

Lesson Description:

ENGAGE	<u>Technology Connection:</u> View footage of a storm surge and the damage caused by a hurricane. There are several selections to choose from. Storm Video. Extreme Weather Stock Footage. *Hurricane footage.* Available: http://www.stormvideo.com/hurricane.html Discussion: 1. What do you see happening in the video? *Storm, storm surge, hurricane*

	2. What caused the high waves? *wind* 3. Why do people evacuate coastal areas when high winds are forecast? *Tides and waves may be higher than normal.*
EXPLORE	Have students observe the effects of wind on the movement of water by blowing through a straw over a shallow water-filled tray. Directions: 1. Fill the tray with water. 2. Using the straw gently blow over the surface of the water. 3. Observe the surface of the water closely. ***Journal Write:*** Record your observations. 4. Repeat the procedure varying the time, strength and location of the wind. 5. Design a data table to record your observations. Observations: · *water moves horizontally and in a single direction* · *direction of water movement is determined by the wind* · *wind energy is transferred to the surface of the water, creating waves and generating a current* · *speed of current is directly proportional to wind speed* · *the Coriolis effect moves water in circles in a clockwise pattern in the Northern Hemisphere*
EXPLAIN	In small groups, discuss the effects of wind on the movement of water. ***Journal Write:*** Based on your observations and group discussion, what is an ocean current? Use evidence from your observations to support your answer.
EXTEND	Provide each student with a world map worksheet.

	Working in small groups, discuss the location and direction of global winds. On the world map, add arrows to indicate the location and direction of global winds. Discussion: 1. Review the location and direction of winds on the overhead or board. 2. Why are the arrows, showing the direction and location of wind, curved? *Due to the Coriolis Effect.* Technology Connection: Have students review the Coriolis Effect through an interactive simulation. EAO Scientific Systems. Internet Campus. *Coriolis Effect.* Available: http://www.eoascientific.com/interactive/the_coriolis_effect/the_coriolis_effect.html ***Journal Write:*** 1. What is the Coriolis Effect? 2. How are moving objects in the Northern hemisphere affected by the Coriolis Effect? 3. What about moving objects in the Southern hemisphere? Do a Think, Pair, Share. Think about the relationship among winds, surface currents, Coriolis Effect. Predict the location of wind-driven currents in the Northern Hemisphere. Use arrows to indicate the location and direction of ocean currents. ***Journal Write:*** How do landmasses influence the direction and movements of currents?

	Teacher Note: If students have difficulty with this concept, let them return to their lab station and observe the effect of the container walls on the direction and speed of a current. G/T Connection: Draw the location of wind-driven currents in the Southern Hemisphere ***Journal Write:*** Compare the ocean currents in the Northern and Southern Hemisphere. Give each group a world map showing the ocean currents. World maps may be found at the following websites: The Remarkable Ocean World. *Whirlpools in your bathtub. Ocean Current Map.* Available: http://www.oceansonline.com/images/currents.gif Advanced Computing Lab / Los Alamos National Laboratory. *Major Oceanic Surface Currents. Ocean Current Map* Available: http://www.acl.lanl.gov/GrandChal/GCM/currents.html Have students compare the predicted ocean currents to the known ocean currents and make modifications as needed. Discussion: Examine the ocean currents. What trends or patterns do you see? Within each ocean, currents move in circles or gyres. The global winds form the currents on the top and bottom of the gyres while landmasses and water pile up forms the currents on the sides. Label the major ocean currents in the North Atlantic Gyre. *Gulf Stream, North Atlantic, Canary Current, and North Equatorial Current*
EVALUATE	***Journal Write:*** 1. Describe the relationship between global winds and surface ocean currents. 2. If a global wind stopped blowing, how will this impact ocean

	currents? 3. What affect does the Coriolis effect have on ocean currents in the Northern and Southern hemispheres?

Materials per lab group:

- World map worksheet
- World map with ocean currents worksheet
- Drinking straw
- Clear tray
- Water

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The effect of wind on the movement of water

Directions:

1. Fill the tray with water.
2. Using the straw gently blow over the surface of the water.
3. Observe the surface of the water closely.

Journal Write:

4. Record your observations.
5. Repeat the procedure varying the time, strength and location of the wind.
6. Design a data table to record your observations.

Resources:

EAO Scientific Systems. Internet Campus. *Coriolis Effect.*

Available: http://www.eoascientific.com/interactive/the_coriolis_effect/the_coriolis_effect.html

Storm Video. Extreme Weather Stock Footage. *Hurricane footage.*

Available: http://www.stormvideo.com/hurricane.html

Advanced Computing Lab / Los Alamos National Laboratory. *Major Oceanic Surface Currents. Ocean Current Map*

Available: http://www.acl.lanl.gov/GrandChal/GCM/currents.html

The Remarkable Ocean World. *Whirlpools in your bathtub. Ocean Current Map.*

Available: http://www.oceansonline.com/images/currents.gif

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Lesson 6: OCEAN CURRENTS

Estimated Time: Two fifty-minute blocks

Indicator(s) Core Learning Goal 1:

1.1.5 The student will explain factors that produce biased data (including incomplete data, using data inappropriately, conflicts of interest, etc.).

1.4.2 The student will analyze data to make predictions, decisions, or draw conclusions.

1.4.6 The student will describe trends revealed by data.

1.4.8 The student will use models and computer simulations to extend his/her understanding of scientific concepts.

1.5.5 The student will create and/or interpret graphics (scale drawings, photographs, digital images, field of view, etc.).

Indicator(s) Core Learning Goal 2:

2.3.1 The student will describe how energy and matter transfer affect Earth systems.
Assessment limits: Oceanic circulation (density differences, daily and seasonal land/sea breezes, Coriolis effect.)

2.3.2 The student will explain how global conditions are affected when natural and human-induced change alter the transfer of energy and matter.
Assessment limits: Ocean-atmosphere land interactions (current changes, continental movement, El Niño, La Niña.)

Student Outcome(s):

The student will be able to explain the role of ocean currents in heat transfer by analyzing sea surface temperatures.

WHAT DOES THE RESEARCH SAY?

Heating of earth's surface and atmosphere by the sun drives convection within the atmosphere and oceans, producing winds and ocean currents. National Research Council, *National Science Education Standards* (1996).

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Solar radiation heats the land masses, oceans, and air. Transfer of heat energy at the boundaries between the atmosphere, the land masses, and the oceans results in layers of different temperatures and densities in both the ocean and atmosphere. The action of gravitational force on regions of different densities causes them to rise or fall—and such circulation, influenced by the rotation of the earth, produces winds and ocean currents.
AAAS, *Benchmarks for Science Literacy* (1993).

Brief Description:

In this lesson students use sea surface temperatures collected by ocean buoys and available from the Globe website to determine how ocean currents transport heat from the equator to the poles.

Background knowledge / teacher notes:

Teacher note: You may download a blank world map from National Geographic Xepeditions. *Xepeditions Atlas*.
Available:
http://www.nationalgeographic.com/xpeditions/atlas/index.html?Parent=world&Mode=d&SubMode=w
(CLICK on the small red magnifying glass, top left, on the world map)
Remind students not to click on world map in upper left corner. It will change the view of the data map. If this happens, they should REFRESH the page.

Lesson Description:

ENGAGE	Discussion: 1. Brainstorm characteristics of ocean currents. *Salty, cold, warm, fast, slow* 2. How do global winds influence the physical characteristics of ocean currents? Read to be informed about drifter buoys. Athena Curriculum Ocean. *Drifter Buoys and Surface Currents.* Available:

	http://vathena.arc.nasa.gov/curric/oceans/drifters/drifters.html NOPP. *Project NOPP Drifters.* Available: http://drifters.doe.gov/ Or other similar websites. ***Journal Write:*** 1. What is the purpose of a drifter buoy? 2. Draw a picture of a drifter buoy 3. How do scientists keep track of a drifter buoy?
EXPLORE	Using the GLOBE website analyze sea surface temperature data from drifter buoys. The Path of Ocean Currents Part One 1. Go to Globe Program. Available: http://www.globe.gov/fsl/welcome/welcomeobject.pl 2. Search for Globe Animations. Go to NOPP (YOTO) Drifters. Available: http://viz.globe.gov/viz bin/show.cgi?l=en&b=g&rg=n&enc=00&&movie=yoto- 3. View the animation NOPP (YOTO) Overview [GIF: 0.62 MB] 4. View the animation Drifters in the Florida Strait [GIF:353kB].
EXPLAIN	***Journal Write:*** 1. Describe the general direction of the drifters. 2. Why are there so many drifter buoys near the Gulf of Mexico? 3. What tends to happen to the drifters when they "escape" the Gulf of Mexico?
EXTEND	Materials: World map, colored pencils Part Two: Sea Surface Temperatures 1. Go to Globe Program. Available: http://www.globe.gov/fsl/welcome/welcomeobject.pl

	2. Find Globe Data. (in the column on the left side). Click on **Globe Maps.** Available: http://viz.globe.gov/viz-bin/home.cgi OR Go to Globe Program. *Globe Visualizations.* Click on **Globe Maps.** Available: http://globe.gsfc.nasa.gov 3. After setting the Category to "**NOPP (YOTO) Ocean Drifters**" and checking that the Map Type is set to "**Points",** click on the **Redraw button**. 4. You can zoom in by clicking on the map OR reset the Map Size option to Medium or Large. 5. Create your own map. Make sure **Category** is still set to "**NOPP (YOTO) Ocean Drifters.**" 6. Change **Map Type** to "**Drifter Tracks**." Click on the **Redraw button**. This may take a while… be patient. A lot of data are being analyzed to construct the map of the drifter tracks. 7. Using colored pencils illustrate the paths and temperatures of the ocean currents in the North Atlantic gyre. ***Journal Write:*** 1. How does the temperature of the Gulf Stream change as it moves up the East coast? Use data from the drifters to support your answer. 2. Suggest reasons to account for the temperature pattern. 3. How do scientists use data from ocean drifters to map ocean currents? 4. Why are there so many drifter buoys? <u>Adaptive strategy</u>: Chunk directions. Pair with a peer helper. <u>G/T Connection:</u> 1. Zoom in on the area at least three times. 2. If there are still too many drifters to easily distinguish the tracks,

	zoom in again. 3. Under the map select “**Choose Drifter**.” 4. Scroll to the bottom of the page. Under "**Other Options**" choose "**Show Table**." Press the **Redraw button** and wait. A table showing all the drifters will appear at the bottom of the page. 5. Above the table in the pull down menu choose “**Select drifters and plot track**." 6. **Click two or three drifters** you want to track 7. Press **Redraw button**. This will generate a map of your drifters. 8. Return to the table at the bottom of the page and **click on the name/number of the drifter.** This will generate a list of drifters. To observe the path of the drifter, click on Map under the drifter. 9. Print or copy your map. ***Journal Write:*** 1. How did the temperature change as the buoy drifted? 2. Compare your drifter data with data from another group. Account for any difference or similarities. In small groups discuss the following: Using your maps of ocean currents and drifter paths, describe the role ocean currents play in heat transfer. Discussion: As a class, discuss the role ocean currents play in the transfer of heat around the globe. The following websites provide good references for the discussion. NASA. *Athena Curriculum: Oceans; Ocean currents from space.* Available: http://vathena.arc.nasa.gov/curric/oceans/drifters/ocecur.html

	Greg Carbon's Exercises for Weather and Climate. *Climate control: Ocean currents.* Available: http://www.cla.sc.edu/geog/faculty/carbone/modules/mods4car/ccontrol/controls/ocean.html Or other similar websites. Multicultural Connection Investigate data collection in one of the many partner nations of the Globe Program. Globe Program. *Globe weather data per country*. Available: http://www.globe.gov/fsl/INTL/table.pl?lang=en or Globe Program. *Partner Countries*. Available: http://www.globe.gov/fsl/INTL/table.pl?lang=en G/T Connection: Create animations comparing data from specific months and years to determine patterns of sea surface temperature variations. NASA. Earth Observatory: *Data and images; sea surface temperature.* Available: http://eob.gsfc.nasa.gov/Observatory/Datasets/sst.avhrr.html
EVALUATE	***Journal Write:*** 1. Describe the role of ocean currents in the transfer of heat around the globe. 2. Use evidence from your drifter buoys to support your statement.

Materials:

- Blank world map
- Colored pencils

The Path of Ocean Currents

Part One

1. Go to Globe Program.

Available: http://www.globe.gov/fsl/welcome/welcomeobject.pl

2. Search for Globe Animations. Go to NOPP (YOTO) Drifters.

Available: http://viz.globe.gov/viz

bin/show.cgi?l=en&b=g&rg=n&enc=00&&movie=yoto-

3. View the animation NOPP (YOTO) Overview [GIF: 0.62 MB]
4. View the animation Drifters in the Florida Strait [GIF:353kB].

Journal Write:

1. Describe the general direction of the drifters.
2. What tends to happen to the drifters when they "escape" the Gulf of Mexico?
3. Why are there so many drifter buoys near the Gulf of Mexico?

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Part Two: Sea Surface Temperatures

1. Go to Globe Program.

Available: http://www.globe.gov/fsl/welcome/welcomeobject.pl

2. Find Globe Data. (in the column on the left side). Click on **GLOBE Maps**

Available: http://viz.globe.gov/viz-bin/home.cgi

3. After setting the Category to "**NOPP (YOTO) Ocean Drifters**" and checking that the Map Type is set to "**Points",** click on the **Redraw button**.
4. You can zoom in by clicking on the map OR reset the Map Size option to Medium or Large.
5. Create your own map. Make sure **Category** is still set to "**NOPP (YOTO) Ocean Drifters.**"
6. Change **Map Type** to "**Drifter Tracks**." Click on the **Redraw button**. This may take a while... be patient. A lot of data are being analyzed to construct the map of the drifter tracks.
7. Using colored pencils illustrate the paths and temperatures of the ocean currents in the North Atlantic gyre.

Journal Write:

1. How does the temperature of the Gulf Stream change as it moves up the East coast? Use data from the drifters to support your answer.
2. Suggest reasons to account for the temperature pattern.
3. How do scientists use data from ocean drifters to map ocean currents?

<u>G/T Connection:</u>

1. Zoom in on the area at least three times.
2. If there are still too many drifters to easily distinguish the tracks, zoom in again.
3. Under the map select "**Choose Drifter**."
4. Scroll to the bottom of the page. Under "**Other Options**" choose "**Show Table**." Press the **Redraw button** and wait. A table showing all the drifters will appear at the bottom of the page.
5. Above the table in the pull down menu choose "**Select drifters and plot track**."
6. **Click two or three drifters** you want to track
7. Press **Redraw button**. This will generate a map of your drifters.
8. Return to the table at the bottom of the page and **click on the name/number of the drifter.** This will generate a list of drifters. To observe the path of the drifter, click on Map under the drifter.
9. Print or copy your map.

Journal Write:

1. How did the temperature change as the buoy drifted?
2. Compare your drifter data with data from another group. Account for any difference or similarities.

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Resources:

Greg Carbon's Exercises for Weather and Climate. *Climate control: Ocean currents.*
Available:
http://www.cla.sc.edu/geog/faculty/carbone/modules/mods4car/ccontrol/controls/ocean.html

NASA. Earth Observatory. *Data and images; sea surface temperature.*
Available:
http://eob.gsfc.nasa.gov/Observatory/Datasets/sst.avhrr.html

Globe Program. *Data visualization*.
Available: http://globe.gsfc.nasa.gov/cgi-bin/map.cgi?l=en&b=g&rg=n

Athena Curriculum Ocean. *Drifter Buoys and Surface Currents.*
Available: http://vathena.arc.nasa.gov/curric/oceans/drifters/drifters.html

Globe Program. *Globe Animations. NOPP (YOTO) Drifters.*
Available:
http://viz.globe.gov/viz bin/show.cgi?l=en&b=g&rg=n&enc=00&&movie=yoto-

Globe Program. *Globe Visualizations.*
Available: http://globe.gsfc.nasa.gov

Globe Program. *Globe weather data per country*.
Available: http://www.globe.gov/fsl/INTL/table.pl?lang=en

NASA.Athena Curriculum. *Oceans; Ocean currents from space.*
Available:
http://vathena.arc.nasa.gov/curric/oceans/drifters/ocecur.html

Globe Program. *Partner Countries*.
Available: http://www.globe.gov/fsl/INTL/table.pl?lang=en

NOPP. *Project NOPP Drifters.*
Available: http://drifters.doe.gov/

National Geographic Xepeditions. *Xepeditions Atlas*.
Available:
http://www.nationalgeographic.com/xpeditions/atlas/index.html?Parent=world&Mode=d&SubMode=w

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Lesson 7: BOUNDARY CURRENTS

Estimated Time: Two fifty-minute blocks

Indicator(s) Core Learning Goal 1:

1.1.2 The student will modify or affirm scientific ideas according to accumulated evidence.

1.2.3 The student will formulate a working hypothesis.

1.2.7 The student will use relationships discovered in the lab to explain phenomena observed outside the laboratory.

1.4.2 The student will analyze data to make predictions, decisions, or draw conclusions.

1.4.8 The student will use models and computer simulations to extend his/her understanding of scientific concepts.

1.5.6 The student will read a technical selection and interpret it appropriately.

Indicator(s) Core Learning Goal 2:

2.3.1 The student will describe how energy and matter transfer affect Earth systems.
Assessment limits (at least) -Oceanic circulation (density differences, daily and seasonal land/sea breezes, Coriolis effect)

2.3.2 The student will explain how global conditions are affected when natural and human-induced change alter the transfer of energy and matter.
Assessment limits (at least) –Ocean-atmosphere-land interactions (current changes, continental movement, El Niño, La Niña). Climate type and distribution (temperature and precipitation)

Student Outcome(s):

1. The student will be able to compare ocean boundary currents by analyzing the relationship among global winds, water temperatures and coastal climates.
2. The student will be able to explain how ocean currents affect coastal climates by analyzing data.

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Brief Description:

In this lesson, students examine the relationship among global winds, water temperatures and coastal climates. Using ocean currents, students infer how currents influence coastal climates.

Background knowledge / teacher notes:

Regarding the laboratory investigation listed in Explore, in coastal regions, cooler ocean currents tend to cause cooler land temperatures, and warmer ocean currents tend to cause warmer land temperatures. This activity will allow students to verify this statement and then apply it to the global ocean scale. The following NASA site provides helpful background information relevant to the Gulf Stream Western Boundary currents.

NASA. *The Gulf Stream Western Boundary Current.*

Available:

http://daac.gsfc.nasa.gov/CAMPAIGN_DOCS/OCDST/classic_scenes/06_classics_boundary.html

This activity works best as a small group activity. Using gallon jars punch a hole large enough for the thermometer in the lid of each of the jars (or use sturdy cardboard). The students will need to suspend the thermometers in the jars through their lids. Set up one equipment tray for each group. Each tray should have two jars, two thermometers and some string. The students need access to hot and cold tap water. If you are using glass jars, test hot water in the jars before doing the classroom activity to make sure they do not crack. Also remind the students that the glass will get hot. Use appropriate safety procedures.

Lesson Description:

ENGAGE	Working in small groups, examine the paths of hurricanes. One site with recent storm histories summarized is: WxUSA. *WxUSA Hurricane Information*. Available: http://www.weatherhub.com/Hurricane/

<table>
<tr><td></td><td>Discussion:
1. Where do most hurricanes occur? Warm tropical waters, near the equator
2. Why do hurricanes occur more often on the East Coast of continents in the Northern hemisphere? warm waters, strong winds, and Coriolis effect
Examine a map showing ocean currents. Introduce the concept of eastern and western boundary currents.</td></tr>
<tr><td>EXPLORE</td><td>Provide each student with a world map.
Working in small groups, brainstorm the temperature, speed, flow, and depth of eastern and western boundary currents.
<u>Adaptive Strategy:</u> review the relationship between winds and ocean currents.
Currents originating at the equator are warm; currents originating at the poles are cold.
Have students color a map of ocean currents using red for warm currents and blue for cold currents.

Students, working in pairs, observe the effect of wind strength on current speed and depth.
Journal Write:
Write a hypothesis predicting how the strength of the wind influences an ocean current.

Materials per group of two: clear tray, blue fresh water, clear salt water, drinking straw
Directions:
1. Pour a layer of salt water in a clear tray.
2. Add enough fresh water, colored blue, to make a well defined layer on top.</td></tr>
</table>

	3. Using a drinking straw, simulate winds by blowing across the surface of the water. 4. Vary the strength of the "wind" and observe the effect on the current. Adaptive Strategy: Brainstorm characteristics of currents: speed, size, and depth. Look for these characteristics during the lab. ***Journal Write:*** 1. How does varying the strength of the wind influence the current? *Stronger winds (e.g. trade winds) produce stronger currents (e.g. western boundary currents), affecting movement of water at greater depth. Conversely, weaker winds yield gentler, shallow currents (e.g. eastern boundary currents).* 2. Where in the ocean are the strongest currents? Use evidence from you investigation to support your answer.
EXPLAIN	Discussion: Technology Connection: View the simulation of global circulation and the California currents. San José State University. *The California current.* Available: http://geosun1.sjsu.edu/~dreed/onset/exer11/26.html Using the results of the simulations, what are the characteristics of eastern and western boundary currents? Eastern boundary currents are generally strong, fast, well-defined, warm water currents. ***Journal Write*:** Generate a graphic organizer comparing eastern and western boundary currents.
EXTEND	Can ocean currents affect the climate of coastal regions? Materials per group of four: thermometer-two, jar with lid-two, graph paper-four, beaker of warm water, beaker of cold water

Ocean Currents and Climate

Directions:

1. Suspend a thermometer through the hole in the lid of each jar.
2. Place the jars next to each other and measure the temperature of the air inside each jar.
3. Plot the air temperature versus time on graph paper.
4. Record measurements until the temperature in both jars is about the same temperature
5. Fill one jar half-full with warm water and one jar half-full with cold water.
6. Wait one minute and take the temperature of air above the water in each jar.
7. Take additional temperature readings every minute for five minutes.

***Journal Write*:**

1. How does water temperature influence air temperature?
2. Write a hypothesis to predict how ocean currents affect coastal climates.

<u>Technology Connection</u>:

Use the map of surface currents and sea surface temperature map on the website to determine if your hypothesis is correct.

San José State University . *Western and Eastern Boundary Currents.* Available: http://geosun1.sjsu.edu/~dreed/onset/exer11/23.html

Journal Write:

Explain why Capetown, at the tip of South Africa, has a cool mild climate whereas Durban, a few hundred miles to the east, is very hot and humid.

INTEREST CENTER

Read about how an accident led to an investigation of ocean currents.

	Ocean Planet Smithsonian. *Staying on top. These shoes just did it.* Available: http://seawifs.gsfc.nasa.gov/OCEAN_PLANET/HTML/oceanography_currents_2.html
EVALUATE	***Journal Write***: 1. Compare eastern and western boundary currents. Be sure to discuss the influence of global winds, water temperatures and coastal climates. 2. Explain how ocean currents affect coastal climates. Cite data from your readings to support your answer.

Materials per lab group:

- Red and blue colored pencils-four
- World map with ocean currents worksheet- four
- Graph paper- four
- Drinking straw-two
- Clear tray- two
- Salt water
- Fresh water
- Blue food coloring
- Glass jars with lids-two
- Thermometers-two
- Hot water
- Cold water

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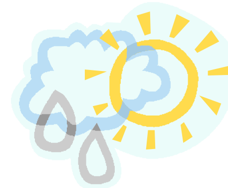


Ocean Currents and Climate

Materials per group of four: thermometer-two, jar with lid-two, graph paper-four, beaker of warm water, beaker of cold water

Directions:

1. Suspend a thermometer through the hole in the lid of each jar.
2. Place the jars next to each other and measure the temperature of the air inside each jar.
3. Plot the air temperature versus time on graph paper.
4. Record measurements until the temperature in both jars is about the same temperature
5. Fill one jar half-full with warm water and one jar half-full with cold water.
6. Wait one minute and take the temperature of air above the water in each jar.
7. Take additional temperature readings every minute for five minutes.

Journal Write:

1. How does water temperature influence air temperature?
2. Hypothesize how boundary currents might affect coastal climates.

Resources:

San José State University. *The California current.*

http://geosun1.sjsu.edu/~dreed/onset/exer11/26.html

NASA. *The Gulf Stream Western Boundary Current.*

Available:

http://daac.gsfc.nasa.gov/CAMPAIGN_DOCS/OCDST/classic_scenes/06_classics_boundary.html

Ocean Planet Smithsonian. *Staying on top. These shoes just did it.*

Available:

http://seawifs.gsfc.nasa.gov/OCEAN_PLANET/HTML/oceanography_currents_2.html

WxUSA. *WxUSA Hurricane Information.*

Available: http://www.weatherhub.com/Hurricane/

San José State University . *Western and Eastern Boundary Currents.*

http://geosun1.sjsu.edu/~dreed/onset/exer11/23.html

Earth/Space Systems Science
Unit III: The Hydrosphere

Lesson 7A: EKMAN SPIRAL **G/T Honors**

Estimated Time: One fifty-minute block

Indicator(s) Core Learning Goal 1:

1.4.2 The student will analyze data to make predictions, decisions, or draw conclusions.

1.4.6 The student will describe trends revealed by data.

1.4.8 The student will use models and computer simulations to extend his/her understanding of scientific concepts.

1.4.9 The student will use analyzed data to confirm, modify, or reject an hypothesis.

Indicator(s) Core Learning Goal 2:

2.3.1 The student will describe how energy and matter transfer affect Earth systems. Assessment limits: Oceanic circulation (density differences, daily and seasonal land/sea breezes, Coriolis effect.)

Student Outcome(s):

The student will be able to determine the direction of a surface current by interpreting Ekman spiral and Ekman transport.

Brief Description:

Students explore the concept of the Ekman Spiral by constructing a model and analyzing its effect on water movement.

Background knowledge / teacher notes:

The Ekman spiral is one of the oldest results in dynamical oceanography. It was first proposed (conceptually) by the great Norwegian explorer Fridtjof Nansen. As part of a polar expedition in the late 1890s, Nansen froze his ship *Fram* into the ice north of Spitzbergen Island and allowed it to drift for more than two years. During the expedition he noticed that the drift of the boat was generally to the right of the wind. Nansen proposed that this motion was the result of the Coriolis force, which causes objects to veer to the right in the Northern Hemisphere and to the left in the

Southern Hemisphere. He supposed further that as the ice pushed on the water immediately below it, that water would move still further to the right of the wind, though a little more slowly. Extended down through the water column, the result would be a spiral structure.

Although the mathematics behind this spiral were formalized by V. Walfrid Ekman in 1905, the spiral itself was not seen in the open ocean until 1986, by Jim Price, Robert Weller, and Becky Schudlich of the Woods Hole Oceanographic Institution. The spiral they found, however, was due to a different set of dynamics, and did not really resemble Ekman's.

The Ekman circulation pattern in the ocean forms from the balance between the force of wind and the Coriolis effect. Balance of wind force and Coriolis effect leads to a net "transport" of water to the right of the wind in the Northern Hemisphere.
The following site provides images and explanations of the Ekman spiral as it relates to upwelling: NASA. *Ocean color data and analysis.*
Available:
http://daac.gsfc.nasa.gov/CAMPAIGN_DOCS/OCDST/classic_scenes/02_classics_benguela.html

Lesson Description:

ENGAGE	Discussion/demonstration: Have students observe the density column in a clear pan at least 10 cm deep. Discuss the make up of water. *Layers* Using a hair dryer demonstrate that as wind/energy moves over the surface of the water, it sets the water layers in motion. The effect of the wind on the water mass is best observed from the side. Give each team of students a stack of five books. Each book represents a layer of water.

	Students gently shove the edges of the top three books and observe the results. Challenge students to apply their knowledge of the Coriolis Effect to motion of the books/layers of water. Using books, each student group demonstrates and explains their response to this challenge. *As each layer of water is set in motion, it transfers energy to the layer beneath it, setting it in motion. Note that the energy and thus motion decreases with depth.*
EXPLORE	Technology Connection: Students detect an Ekman spiral by observing a laboratory demonstration. GFD-DENNOU Club. *Ekman Spiral*. *Observing currents caused by wind on a rotating system.* Available: http://dennou-t.ms.u-tokyo.ac.jp/library/gfd_exp/exp_e/exp/ek/
EXPLAIN	***Journal Write:*** 1. Draw an Ekman spiral on the board or use a model made of a straw and paper arrows to demonstrate the 3-D effect. 2. Brainstorm where the majority of water is actually being transported. *90° to the wind. This is Ekman transport.*
EXTEND	Have students observe the effect of winds on the Ekman spiral and Ekman transport over time by viewing satellite data depicting the interaction among sea surface temperatures, winds, and currents. Satellite data located at following websites: NOAA.TAO. *Sea Surface Temperature, Winds, 20°C Isotherm, and Upper Ocean Temperature and Current at the Equator.* Available: http://www.pmel.noaa.gov/toga-tao/vis/tao-vis.html NOAA.TAO. *Sea Surface Temperature, Winds, 20°C Isotherm, and*

	Upper Ocean Temperature and Current at the Equator. Available: http://www.pmel.noaa.gov/tao/vis/gif/sst-wind-cur-eqt-20c-med.gif (This should link directly to the movie. If not go to the URL above and click on GIF animation.) Career Connection: Investigate a Marine Career. NOAA. *Marine Careers*. Available: http://www.marinecareers.net/
EVALUATE	***Journal Write*:** 1. Explain how the straw mobile demonstrates the Ekman spiral. 2. What are the advantages and disadvantages of the model?

Materials per lab group:

- Five books
- Clear pan 10cm deep
- Corn syrup
- Syrup
- Dish detergent
- Shampoo
- Colored water
- Oil
- Graduated cylinder

Resources:

GFD-DENNOU Club. *Ekman Spiral. Observing currents caused by wind on a rotating system.*
Available: http://dennou-t.ms.u-tokyo.ac.jp/library/gfd_exp/exp_e/exp/ek/

NOAA. *Marine Careers*.
Available: http://www.marinecareers.net/

NASA. *Ocean color data and analysis.*
Available:
http://daac.gsfc.nasa.gov/CAMPAIGN_DOCS/OCDST/classic_scenes/02_classics_benguela.html

NOAA.TAO. *Sea Surface Temperature, Winds, 20°C Isotherm, and Upper Ocean Temperature and Current at the Equator.*
Available: http://www.pmel.noaa.gov/toga-tao/vis/tao-vis.html

NOAA.TAO. *Sea Surface Temperature, Winds, 20°C Isotherm, and Upper Ocean Temperature and Current at the Equator.*
Available: http://www.pmel.noaa.gov/tao/vis/gif/sst-wind-cur-eqt-20c-med.gif

Earth/Space Systems Science
Unit III: The Hydrosphere

Lesson 7B: CONVERGENCE AND GEOSTROPIC CURRENTS **G/T OR HONORS**

Estimated Time: Two fifty-minute blocks

Indicator(s) Core Learning Goal 1:

1.4.2 The student will analyze data to make predictions, decisions, or draw conclusions.

1.4.6 The student will describe trends revealed by data.

1.4.8 The student will use models and computer simulations to extend his/her understanding of scientific concepts.

1.4.9 The student will use analyzed data to confirm, modify, or reject an hypothesis.

Indicator(s) Core Learning Goal 2:

2.3.1 The student will describe how energy and matter transfer affect Earth systems. Assessment limits: Oceanic circulation (density differences, daily and seasonal land/sea breezes, Coriolis effect.)

Student Outcome(s):

The student will be able to explain the effect of Ekman Transport and the Coriolis effect on convergence and the formation of geostrophic currents by analyzing ocean topography and creating a system diagram.

Brief Description:

This is an introductory lesson on upwelling, convergence and interpreting data. Although students see evidence of El Nino in the data from the buoys it is not emphasized in this lesson.

Background knowledge / teacher notes:

One type of current motion in the oceans of the hydrosphere is due to horizontal pressure gradients, similar to the horizontal pressure gradients found in the atmosphere. (See Unit I). Water in the ocean flows in a direction that "smoothes out" horizontal pressure differences. One cause of these horizontal pressure differences is the boundary of a continent. These continental boundaries are an obstacle to current flow.

When Coriolis force acts on moving water and is balanced by a horizontal pressure-gradient force the current that is generated is called a geostrophic current. As water is "piled up" against a continental boundary, a slope of water may be created. The current created will flow at an angle to the horizontal pressure gradient instead of down the pressure gradient.

Lesson Description:

ENGAGE	Discussion: Since ocean currents vary in strength and volume, we might expect to see a pile up of water in one area of the ocean. Predict where this **pile up, or convergence,** might occur. *In the Northern Hemisphere, we would expect water to pile up in the northeast and southwest portions of the gyre*. Have students draw Ekman transport for each of the currents in the Northern Pacific Gyre on their Current Map. In small groups, hypothesize the effect of the Ekman transport on the level of the sea surface inside a gyre. Provide students with a diagram of Ekman spiral and geostrophic currents. Download from the following websites: Texas A & M University and the Jason Project. *"Current" events: Forces and pressures on currents* Available: http://oceanworld.tamu.edu/students/currents/currents3.htm Texas A & M University and JASON Project. *Ekman Spiral.* Available: http://oceanworld.tamu.edu/students/currents/
EXPLORE	In small groups, students perform the investigation: "Sea Level Slopes and Surface Current," from JPL. (1998). Visit to an Ocean Planet CD-ROM.

Or JPL. *Sea Level Slopes and Surface Currents.*

Available: http://topex-www.jpl.nasa.gov/education/activities/ts2siac5.pdf

Real time data for sea surface heights can be downloaded from:

NOAA: *TAO/TRITON data display*

Available:

http://www.pmel.noaa.gov/toga-tao/realtime.html

Select "Time Series" from the menu.

SEA LEVEL SLOPES AND SURFACE CURRENTS

Visit to an Ocean Planet

Introduction

Measuring the topography of the sea's surface is a challenging task. The TOPEX/Poseidon radar altimeter mounted on an Earth-orbiting satellite, can measure the sea surface.

Figure 1: The North Atlantic Ocean map shows the ground track of the satellite carrying the TOPEX/Poseidon altimeter.

As the satellite passes over a section of the ocean, the altimeter sends radar beams down to the sea surface, where they are reflected back to the satellite. The round-trip travel time allow scientists to measure the distance from the satellite to sea surface to within a few centimeters. This actual distance is compared to what the sea surface would have if the ocean were still (no currents, waves, etc.). The height differences show where the ocean's hills and valleys are and the slope of the surface between them.

The following activity uses some of these sea height differences, calculated from TOPEX/Poseidon data to investigate the relationship between sea surface topography and ocean surface currents.

	Directions: 1. Examine the table of sea surface height differences. The table shows the data from the radar altimeter compared to the sea surface if it were still and flat. The two measurements were then subtracted and the differences are shown in the table. 2. Using graph paper, plot the sea surface height data shown in the table. ***Journal Write:*** 3. What observations can you make about the surface of the sea? Use evidence from the table or graph to support your answer. 4. What might cause these changes in the topography of the sea? 5. Water flows down hill. Using an arrow, show the movement of water, the Gulf Stream, on your graph. 6. Turn your graph so that the latitude points are oriented correctly. (40ºN should be at the top and 38ºN at the bottom) 7. Why does the path of the Gulf Stream curve to the right? 8. Surface currents are strongest on the steepest slopes and weakest on the gentlest slopes. Since the Gulf Stream is one of the strongest surface currents, what does that indicate about the sea surface heights? 9. Because of the relationship between sea surface slope and surface currents, paths of currents can be used to predict where the sea heights differ. For example, observations show that in the Southern Hemisphere, the Peru Current flows northward along the coasts of Chile and Peru. Adaptive strategy: Chunk directions. Pair students with a peer helper.
EXPLAIN	***Journal Write:***

	Predict whether the sea heights will be higher to the left (or west) of the Peru Current than they are to the right (or east). Use evidence to support your answer.
EXTEND	Part One 1. Examine the sea surface topographical map of the Gulf of Mexico. 2. Draw a profile or write a description illustrating the topography of the Gulf Stream Current and associated eddies. Colorado Center for Astrodynamics Research (CCAR). *Gulf of Mexico Near-Real-Time Altimeter Data Home Page*. Available: http://www-ccar.colorado.edu/research/gom/html/gom_nrt.html Go to the site and click on the image of the Gulf of Mexico. Career Connection: Investigate the variety of satellite missions and laboratories and professional scientists that work together to provide the data in the above image processing website. Part Two Having realized that water piles up in the middle of the gyres, students perform an investigation to discover geostrophic currents. Sea Surface Topography 1. Place piece of filter paper on a turntable. 2. Form a pile of sand in the center of the table. The pile should be large enough to easily observe sand flowing down the sides. ***Journal Write:*** 3. Describe or diagram the sand flowing down the pile. 4. What force caused the sand to flow down the pile? *Gravity* 5. Rotate the table to the left while observing the pile of sand. ***Journal Write:***

	6. Draw a picture of the sand after the rotation. 7. Describe the differences between the patterns of the two sand flows. 8. What force caused the change in the direction of the sand flow? Coriolis Effect 9. Describe how these two forces interact on a particle of sand. Ask students to apply the results of the investigation to the pile up of water in the gyres. Teacher Note: Help students realize that gravity acting on the pile of water results in a force that pushes the water outward and down a pressure gradient. The Coriolis effect deflects the water to the right (in the Northern Hemisphere) in a curved path. When these two forces balance, a geostrophic current flows around the gyre creating boundary currents.
EVALUATE	***Journal Write*:** 1. Using your knowledge of Ekman Transport and the Coriolis effect, predict where convergence will occur. 2. Create a system diagram of a geostrophic current and explain how it is formed.

Materials per lab group:

- Four ocean current maps
- Turntable
- Filter paper
- Sand
- Spoon
- Graph paper

Earth/Space Systems Science
Unit III: The Hydrosphere

Sea Level Slopes and Surface Currents

Visit to an Ocean Planet

Introduction

Measuring the topography of the sea's surface is a challenging task. The TOPEX/Poseidon radar altimeter mounted on an Earth-orbiting satellite, can measure the sea surface.

Figure 1. North Atlantic Map.

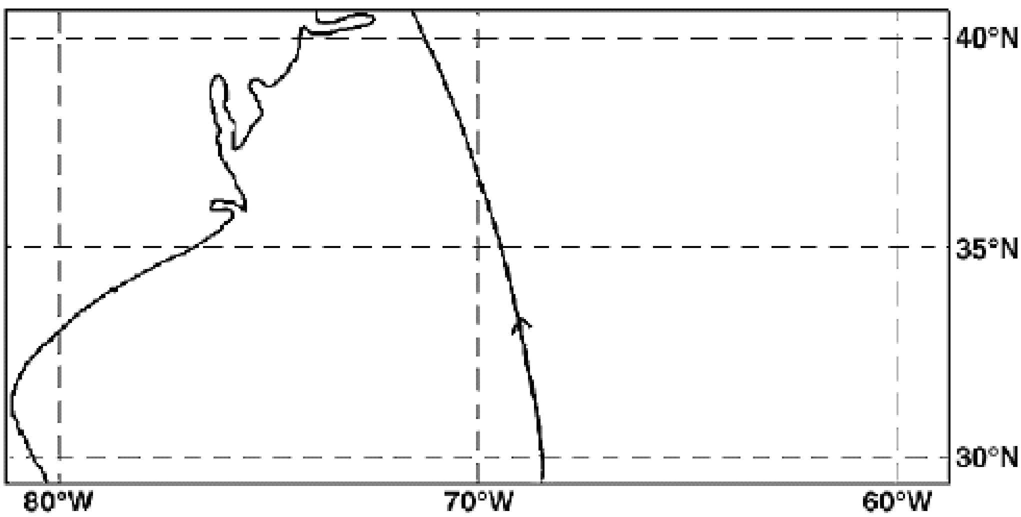


Figure 1: The North Atlantic Ocean map shows the ground track of the satellite carrying the TOPEX/Poseidon altimeter.

As the satellite passes over a section of the ocean, the altimeter sends radar beams down to the sea surface, where they are reflected back to the satellite. The round-trip travel time allow scientists to measure the distance from the satellite to sea surface to within a few centimeters. This actual distance is compared to what the sea surface would have if the ocean were still (no currents, waves, etc.). The height differences show where the ocean's hills and valleys are and the slope of the surface between them.

The following activity uses some of these sea height differences, calculated from TOPEX/Poseidon data to investigate the relationship between sea surface topography and ocean surface currents.

Directions:

1. Examine the table of sea surface height differences. The table shows the data from the radar altimeter compared to the sea surface if it were still and flat. The two measurements were then subtracted and the differences are shown in the table.

Sea Surface Height Differences					
Latitude (N)	38.6	38.8	39.0	39.2	39.4
Height (m)	+0.15	+0.11	+0.10	-0.09	-0.46

2. Using graph paper, plot the sea surface height data shown in the table.

Journal Write:

3. What observations can you make about the surface of the sea? Use evidence from the table or graph to support your answer.

4. What might cause these changes in the topography of the sea?
5. Water flows down hill. Using an arrow, show the movement of water, the Gulf Stream, on your graph.
6. Turn your graph so that the latitude points are oriented correctly. (40°N should be at the top and 38°N at the bottom)
7. Why does the path of the Gulf Stream curve to the right?
8. Surface currents are strongest on the steepest slopes and weakest on the gentlest slopes. Since the Gulf Stream is one of the strongest surface currents, what does that indicate about the sea surface heights?
9. Because of the relationship between sea surface slope and surface currents, paths of currents can be used to predict where the sea heights differ. For example, observations show that in the Southern Hemisphere, the Peru Current flows northward along the coasts of Chile and Peru.

Journal Write:

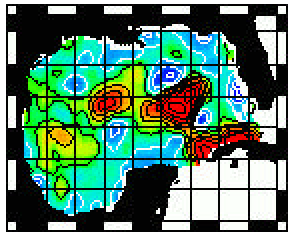
10. Predict whether the sea heights will be higher to the left (or west) of the Peru Current than they are to the right (or east). Use evidence to support your answer.

SOURCE

The Maury Project, American Meteorological Society

Earth/Space Systems Science
Unit III: The Hydrosphere

Sea Surface Topography



Directions:

1. Place piece of filter paper on a turntable.
2. Form a pile of sand in the center of the table. The pile should be large enough to easily observe sand flowing down the sides.

Journal Write:

3. Describe or diagram the sand flowing down the pile.
4. What force caused the sand to flow down the pile?
5. Rotate the table to the left while observing the pile of sand.

Journal Write:

6. Draw a picture of the sand after the rotation.
7. Describe the differences between the patterns of the two sand flows.
8. What force caused the change in the direction of the sand flow?
9. Describe how these two forces interact on a particle of sand.

Resources:

Texas A & M University and the Jason Project. *"Current" events: Forces and pressures on currents*
Available: http://oceanworld.tamu.edu/students/currents/currents3.htm

Texas A & M University and JASON Project. *Ekman Spiral.*
Available: http://oceanworld.tamu.edu/students/currents/

Colorado Center for Astrodynamics Research (CCAR). *Gulf of Mexico Near-Real-Time Altimeter Data Home Page*.
Available: http://www-ccar.colorado.edu/research/gom/html/gom_nrt.html

Prentice Hall. (1999). The Earth System. *The circulation of oceans*. pp. 79-96.

JPL. (1998). Visit to an Ocean Planet CD-ROM. *Sea Level Slopes and Surface Currents.*

JPL. *Sea Level Slopes and Surface Currents.*
Available: http://topex-www.jpl.nasa.gov/education/activities/ts2siac5.pdf

Ocean Planet Smithsonian. *Staying on top. These shoes just did it.*
Available:
http://seawifs.gsfc.nasa.gov/OCEAN_PLANET/HTML/oceanography_currents_2.html

NOAA: *TAO/TRITON data display*.
Available: http://www.pmel.noaa.gov/toga-tao/realtime.html

Earth/Space Systems Science
Unit III: The Hydrosphere

Lesson 8: DENSITY

Estimated Time: Two fifty-minute blocks

Indicator(s) Core Learning Goal 1:

1.2.7 The student will use relationships discovered in the lab to explain phenomena observed outside the laboratory.

1.4.2 The student will analyze data to make predictions, decisions, or draw conclusions.

1.4.4 The student will determine the relationships between quantities and develop the mathematical model that describes these relationships.

1.4.6 The student will describe trends revealed by data.

Indicator(s) Core Learning Goal 2:

2.3.1 The student will describe how energy and matter transfer affect Earth systems. Assessment limits: Oceanic circulation (density differences, daily and seasonal land/sea breezes, Coriolis effect.)

Student Outcome(s):

The student will be able to determine factors that influence the density of water by performing laboratory investigations.

Brief Description:

In this lesson, students examine factors that influence density. They explore the relationship among temperature, salinity and density by analyzing data from laboratory investigations.

Background knowledge / teacher notes:

Temperature and salinity (the amount of dissolved salts in the water) affect the density of the water. The colder fresh water is, the denser it becomes, up to a point. At about 4 degrees Celsius water reaches its temperature of maximum density. Below this temperature water becomes less dense. Below 4 degrees Celsius water begins to form a crystal lattice known as ice. Ice floats because it is less dense than liquid water. Ice takes up about 9% more space than liquid water. Increasing volume decreases density.

Salinity also changes density. The saltier the water, the denser it becomes. Adding salt increases mass thus increasing density.

Lesson Description:

ENGAGE	Provide each pair of students the following materials: small dish, water, and two small pieces of aluminum foil. Encourage students to use these materials and investigate the relationship between mass, volume and density. Sample procedures: 1. Fill the small dish with water. 2. Place the foil on the water so that none it is not touching the container. 3. What happens? *The foil will float.* 4. Fold the aluminum foil into the smallest square possible. 5. Place the folded aluminum foil on the water. Observe what happens. *The foil will sink.* <u>Adaptive Strategy:</u> This may be done as a class demonstration. Weigh the aluminum foil before and after to show that the mass has not changed. Discussion: 1. What is the relationship among mass, volume and density? 2. <u>Adaptive Strategy</u>: 3. Why did the aluminum float at first, but sank after it was folded? 4. What is the formula for density? *Density is mass divided by volume.* 5. What is the relationship among mass, volume and density?

	<u>Adaptive Strategy</u>: If students do not understand the relationship between mass and density, allow them to do the following investigation. Materials: small dish, water, a small piece of aluminum foil. Directions: 1. Fill the small dish with water. 2. Using the aluminum design a boat to carry the maximum number of pennies. 3. Place the boat in the water. 4. Add items such as pennies to the boat until it sinks. Discussion: 1. Why did the "boat" sink? 2. What happened to the density of the "boat"? 3. What is the relationship between mass, volume and density?
EXPLORE	Using the materials, have students determine the density of fresh water. Materials: triple beam balance, graduated cylinder, distilled water ***Journal Write:*** 1. Design a data table to record the mass and volume of the distilled water. 2. What is the density of fresh water? <u>Adaptive Strategy</u>: Explain how to determine the volume of a liquid. Fill the cylinder with water to the 10 mL line. This is the volume. Model how to use a triple beam balance and read a meniscus. Allow students to use calculators.
EXPLAIN	***Journal Write:*** 1. What is the relationship between mass and density? *As mass increases, density increases.* 2. What is the relationship between volume and density? *As volume increases, density decreases.* 3. What is the density of fresh water? *1g/mL or 1g/cc*

EXTEND	Working in pairs, students design an experiment to test either the effect of salt on the density of water or the effect of temperature on the density of water. Materials: eyedropper, triple beam balance, salt, filter paper, small beaker, spoon, and stirring rod. ***Journal Write:*** 1. Write a hypothesis about the effect of salt or temperature on the density of water. 2. Using the materials provided, write procedures for your laboratory investigation. 3. Design a data table to record your results. 4. Have the teacher review your procedures before beginning the experiment. Adaptive Strategy: Give students an experimental design sheet. Work with students to write procedures. Sample procedures: 1. Design a data table to record the changes in volume and density. 2. Fill the graduated cylinder to the 8 mL line. Record its volume in the data table. 3. Determine the mass of a filter paper. 4. Measure two grams of salt. 5. Add two grams of salt to the cylinder and stir. 6. Read the water level inside the cylinder. This is the volume. Record the volume in the data table. 7. Divide the mass of the water inside the cylinder by its new volume. This is the density of the salt water. 8. Record the density of the salt water in the data table. How does temperature influence density? Materials per lab group: three beaker, hot plate, blue colored ice cubes,

	three eyedropper, green cold water, red colored hot water. Sample procedures: 1. Design a data table to record temperature and density observations. 2. Fill the beaker three fourths of the way full with room temperature water. 3. Gently add one or two colored ice cubes to the beaker. 4. Observe the location of the ice. 5. Fill an eyedropper with the colored cold water. Gently add this water to the beaker. 6. Observe the final location of the cold water. 7. Fill an eyedropper with the colored hot water. Gently add this water to the beaker. 8. Observe the final location of the hot water. Each group shares their results with the class. Then, working in small groups, students answer the journal questions. ***Journal Write:*** 1. Compare the densities of ice, warm water and cold water. 2. How does temperature influence density? Use evidence from your investigation to support your answer. 3. Why does temperature influence density? 4. Compare the densities of the salt water and the fresh water. 5. How does salt influence density? Use evidence from your investigation to support your answer. 6. Why does salt influence density?
EVALUATE	***Journal Write:*** 1. What factors influence density? *Salinity and temperature* 2. What is the relationship between salinity and density? Use evidence from your laboratory investigation to support your answer. 3. What is the relationship between temperature and density? Use

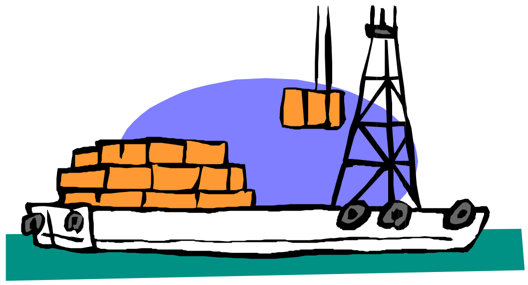
	evidence from your laboratory investigation to support your answer.

Materials per lab group:

- Thermometer
- Eye dropper
- Salt
- Beakers
- Hot plates
- Aluminum foil
- Small petri dish
- Ice
- Spoons
- Stirring rods
- Food coloring: red, green, blue

Earth/Space Systems Science
Unit III: The Hydrosphere

Will It Float or Sink?



Materials: small dish, water, a small piece of aluminum foil, pennies, water

Directions:

1. Fill the small dish with water.
2. Using the aluminum design a boat that will carry the largest number of pennies.
3. Place the boat in the water.
4. Add items such as pennies to the boat until it sinks.

Earth/Space Systems Science
Unit III: The Hydrosphere

Lesson 9: VERTICAL DISTRIBUTION

Estimated Time: Two fifty-minute blocks

Indicator(s) Core Learning Goal 1:

1.2.1 The student will identify meaningful, answerable scientific questions.

1.2.2 The student will pose meaningful, answerable scientific questions.

1.2.7 The student will use relationships discovered in the lab to explain phenomena observed outside the laboratory.

1.4.2 The student will analyze data to make predictions, decisions, or draw conclusions.

1.4.6 The student will describe trends revealed by data.

Indicator(s) Core Learning Goal 2:

2.3.1 The student will describe how energy and matter transfer affect Earth systems. Assessment limits: Oceanic circulation (density differences, daily and seasonal land/sea breezes, Coriolis effect).

Student Outcome(s):

The student will be able to predict the structure of the deep ocean waters by applying the results of laboratory investigations.

Brief Description:

In this lesson, students conduct a laboratory investigation to determine how differences in the surfaces waters may lead to stratification of the deep ocean waters.

Background knowledge / teacher notes:

Teacher Note:

For the Explore section: Prior to class, make the following solutions: green very dense salt water, red salt water and blue fresh water. If possible, store in one liter containers at each lab station. This should be enough for five classes.

For the Extend section: Prior to class fill two 500 mL beakers with equal amounts of salt water. Place one beaker in a freezer until a layer of ice forms.

The relative density of a particular volume or segment of seawater controls the depth at which that water will occur in the ocean. Changes in density, resulting from processes that occur primarily at the surface, are prime causes of slow deep-ocean currents.

The following sites contain information about oceans and ocean currents, including information about vertical distribution.

University of California, Santa Cruz. *Oceans and coasts.*
Available: http://www.es.ucsc.edu/%7Ees10jsr/classnotes/Lectures/lecture.11.html

JPL. NASA. *Salinity and deep ocean currents*.
Available: http://topex-www.jpl.nasa.gov/education/activities/ts1siac2.pdf

Lesson Description:

ENGAGE	Discussion: Draw a large rectangle on the board or overhead. This represents a cross section of the ocean. Add waves to the top and ocean floor to the bottom. Remind students that the average depth of the ocean is 2.5 miles. Think-Pair-Share 1. Surface currents only affect the ocean to a depth of about 100m. What's the ocean water like below that depth? 2. Imagine you are in a submersible diving to the bottom of the ocean. The purpose of your dive is to compare the water at the bottom to the water at the surface. 3. Predict what the water will be like at the bottom of the ocean. 4. What factors might cause the water at the bottom to be different from the water at the surface? *The wind mixes surfaces waters, but below the wind, water will separate out according to differences in*

	salinity, temperature and density. Discuss these predictions as a class.
EXPLORE	Divide a lab group of four into pairs. Each pair will investigate either the effect of temperature or salinity on the formation of deep ocean waters. ***Journal Write:*** Write a hypothesis predicting the effect of temperature or salinity on the formation of deep ocean currents. Temperature of Deep Ocean Water Materials per lab group: 400mL beaker, small beaker (50 mL), hot water, cold water, green, red, blue food coloring, hot plate Teacher Note: Prior to class make use food coloring to make red hot water, green cold water and blue room temperature water. Directions: 1. Fill the LARGER beaker half full of green colored cold water. 2. Slowly pour RED hot water into the beaker along the surface. DO NOT DISTURB THE BEAKER! 3. Slowly siphon blue room temperature water to the middle of the beaker. ***Journal Write*:** Draw your container and label all the layers. *There should be three layers.* Adaptive Strategy: Model how to siphon water from one beaker to another and how to control the speed of the water by manipulating the height of the small beaker. Teacher Note: Avoid mouth siphoning. Salinity of Deep Ocean Water.

	Materials per lab group: 400mL beaker, small beaker (50 mL), water, salt, teaspoon, green, red, blue food coloring, 1ft. plastic tubing Teacher Note: Prior to class make the three salinities and store in 1L containers at each lab station. 1. Directions: 2. Fill the LARGER beaker half full of green colored salt water. 3. Make dense seawater by adding salt to the water and stir vigorously. Add salt until some remains undissolved even after vigorous stirring. 4. Slowly siphon RED fresh tap water into the beaker along the surface. DO NOT DISTURB THE BEAKER! 5. Slowly siphon regular (blue) seawater to the middle of the beaker. ***Journal Write*:** Draw your container and label all the layers. *There should be three layers.*
EXPLAIN	Share your results with your lab group. ***Journal Write:*** 1. Each of these layers represents a water mass. Describe their physical characteristics. 2. What caused the formation of the layers? *Differences in salinity, temperature or density.* 3. Do these results support your hypothesis? Use evidence from the investigation to support your answer.
EXTEND	***Journal Write:*** 1. Draw a large rectangle on the board or overhead. This represents a cross section of the ocean. Add waves to the top and ocean floor to the bottom. 2. Discuss and then predict what the ocean waters look like below the

	surface currents. Write your prediction. 3. If the ocean waters are layered below the surface currents, how did they become layered or stratified? *Differences in density cause saltier/colder water to sink.* 4. What processes could lead to salinity and temperature differences in the surface waters? *Evaporation, precipitation, river run off…* Give students a world map. Predict where in the world these processes occur. Give students maps of sea surface temperatures and sea surface salinities. Montana State University (using NASA data sets). *Dynamic Sea Surface Temperatures*. Available: http://www.math.montana.edu/~nmp/materials/ess/hydrosphere/advanced/adv_sea_temp/ Ocean Globe. UCLA. *Isohalines-Surface Salinities Lab.* Available: http://www.msc.ucla.edu/oceanglobe/pdf/iso_surf_sal.pdf ***Journal Write:*** 5. Examine the maps; how well did your predictions compare the to actual data?
EVALUATE	***Journal Write:*** Write a hypothesis about structure of the deep ocean water. Use evidence from the investigations to support your hypothesis.

Materials per lab group:

- Tubing, plastic, at least 1 ft
- Food coloring: red, blue, green
- Beakers: two 400 mL and two 50 mL
- Three containers, large to store water

- Salt
- Stirring rod
- Water cold
- World map
- Hot plate
- Pump for siphoning
- Sea surface salinities map
- Sea surface temperatures map

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Temperature of Deep Ocean Water

Materials: 400mL beaker, small beaker (50 mL), hot water, cold water, green, red, blue food coloring, hot plate

Directions:

1. Fill the LARGER beaker half full of green colored cold water.
2. Slowly pour RED hot water into the beaker along the surface. DO NOT DISTURB THE BEAKER!
3. Slowly siphon blue room temperature water to the middle of the beaker.

Journal Write:

4. Draw your container and label all the layers.

Salinity of Deep Ocean Water.

Materials: 400mL beaker, small beaker (50 mL), water, salt, teaspoon, green, red, blue food coloring, 1ft. plastic tubing

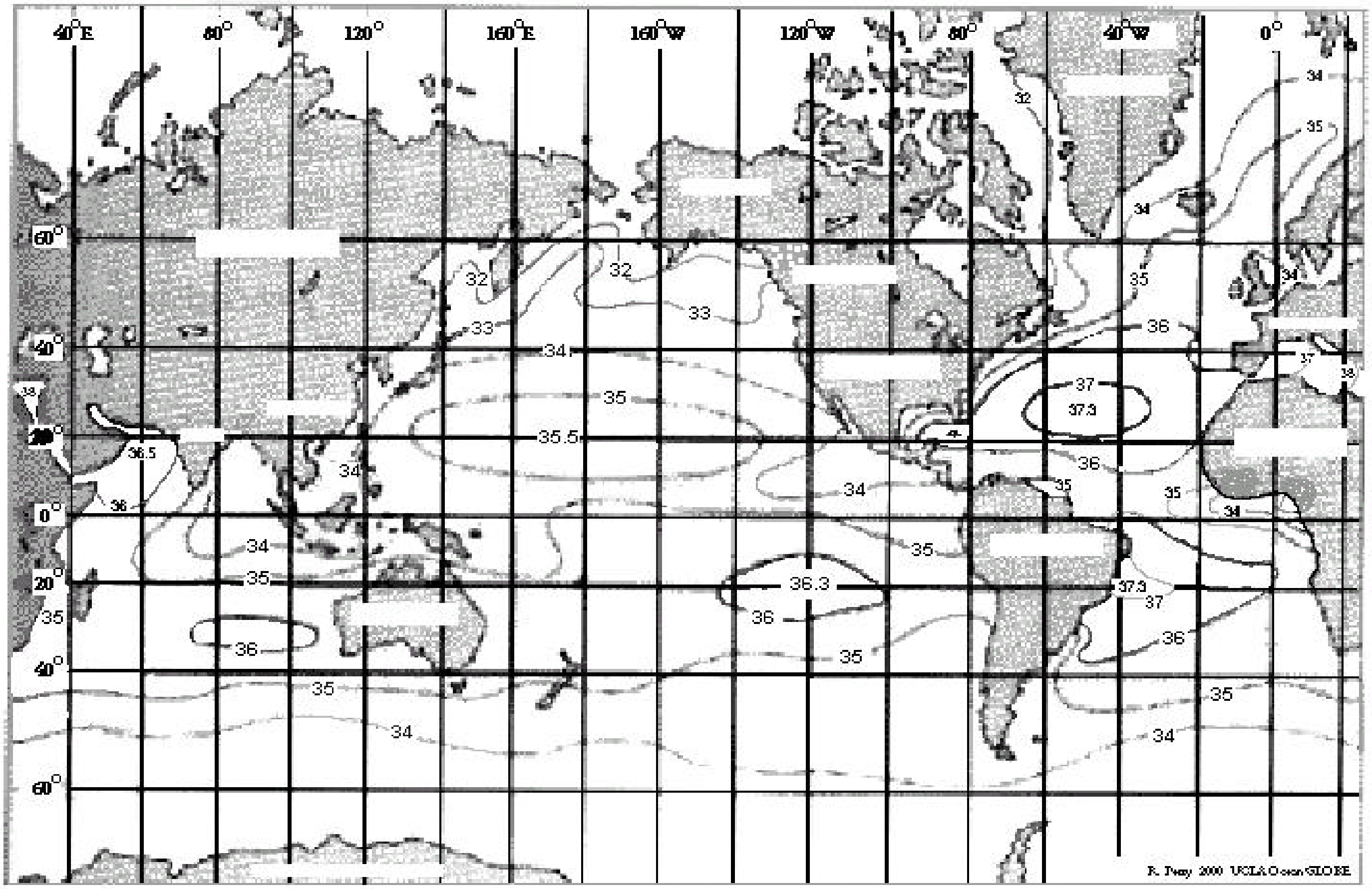
Directions:

1. Fill the LARGER beaker half full of green colored salt water.
2. Make dense seawater by adding salt to the water and stir vigorously. Add salt until some remains undissolved even after vigorous stirring.
3. Slowly siphon RED fresh tap water into the beaker along the surface. DO NOT DISTURB THE BEAKER!
4. Slowly siphon regular (blue) seawater to the middle of the beaker.

Journal Write:

Draw your container and label all the layers.

Sea Surface Salinities

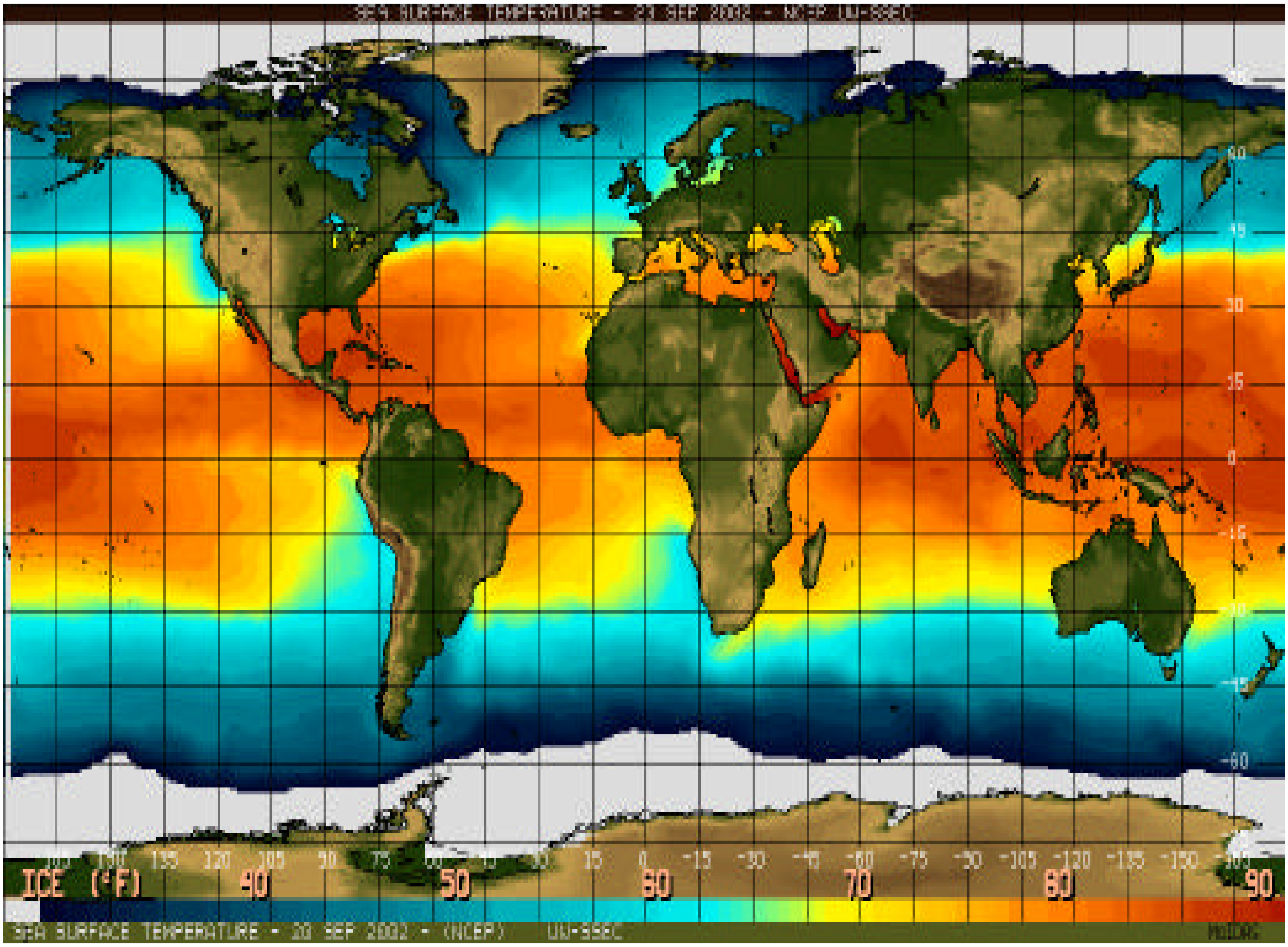


Ocean Globe. UCLA. *Isohalines-Surface Salinities Lab.*

Available: http://www.msc.ucla.edu/oceanglobe/pdf/iso_surf_sal.pdf

Earth/Space Systems Science
Unit III: The Hydrosphere

Sea Surface Temperatures



Montana State University (using NASA data sets*).* *Dynamic Sea Surface Temperatures*.

Available: http://www.math.montana.edu/~nmp/materials/ess/hydrosphere/advanced/adv_sea_temp/

Resources:

Ocean Globe. UCLA. *Isohalines-Surface Salinities Lab.*

Available: http://www.msc.ucla.edu/oceanglobe/pdf/iso_surf_sal.pdf

JPL. NASA. *Salinity and deep ocean currents*.

Available: http://topex-www.jpl.nasa.gov/education/activities/ts1siac2.pdf

University of California, Santa Cruz. *Oceans and coasts.*

Available: http://www.es.ucsc.edu/%7Ees10jsr/classnotes/Lectures/lecture.11.html

Earth/Space Systems Science
Unit III: The Hydrosphere

LESSON 10: CAUSES OF DEEP OCEAN CURRENTS

Estimated Time: Three fifty-minute blocks

Indicator(s) Core Learning Goal 1:

1.2.7 The student will use relationships discovered in the lab to explain phenomena observed outside the laboratory.

1.4.2 The student will analyze data to make predictions, decisions, or draw conclusions.

1.4.6 The student will describe trends revealed by data.

1.4.8 The student will use models and computer simulations to extend his/her understanding of scientific concepts.

Indicator(s) Core Learning Goal 2:

2.3.1 The student will describe how energy and matter transfer affect Earth systems.
Assessment limits: Oceanic circulation (density differences, daily and seasonal land/sea breezes, Coriolis effect.)

Student Outcome(s):

The student will be able to hypothesize the causes of deep ocean currents by performing laboratory investigations and then comparing their results to oceanic data.

Brief Description:

In this lesson students investigate deep ocean circulation. Using a model, students investigate the role of temperature and salinity on deep ocean currents. They then compare the physical model to the Earth's oceans by examining sea surface temperature data. Animation, the "Global Conveyer Belt," assists students in developing their own conceptual model of deep ocean currents.

Background knowledge / teacher notes:

Deep ocean currents are part of the temperature-salinity-driven circulation (thermohaline) of the oceans. Volumes of water in the oceans, similar to air masses in the atmosphere have unique characteristics. Water masses are defined on the basis of their salinity and temperature (and so density). Water masses may travel long distances and still retain their temperature and salinity properties. Deep currents are not affected by winds directly, but instead by temperature and salinity. Seawater becomes denser as its salinity increases. Cooler water is heavier than warmer water, thus it sinks.

A complex conveyer belt of currents is established. Cold winds from Canada cool the waters of the North Atlantic. Dense cold salty water east of Greenland sinks and flows southward at a great depth into the South Atlantic. This water then meets with colder, more dense water from Antarctica. It turns eastward around the tip of Africa, and flows into the Pacific along the western boundary of the ocean basin. The water then flows east as it is deflected by the Asian landmass. Water is warmed as it flows through the Pacific, thus becomes less dense, and rises to the surface. This warm water moves southward across the Pacific basin and turns west, returning to the South Atlantic. It then moves northward to the North Atlantic. The complete cycling of Deep Ocean water takes about 1000 years. Any changes in "conveyer belt circulation" can cause climatic change.

An excellent tutorial is provided at Woods Hole Oceanographic Institution. *A Primer on Ocean Currents*

Available: http://www.whoi.edu/coastal-briefs/Coastal-Brief-94-05.html

The following websites provide excellent background information:

University Corporation for Atmospheric Research, University of Michigan. *Salinity.*

Available: http://windows.arc.nasa.gov/cgi-bin/tour.cgi?link=/earth/Water/salinity.html&cd=false&cdp=/windows3.html&art=ok&frp=/windows3.html&fr=f&sw=false&edu=high

Lesson Description:

ENGAGE	Think-Pair-Share Scientists have predicted the existence of deep ocean currents. What

	factors might lead to the formation of deep ocean currents? *Temperature and salinity changes at the surface.*
EXPLORE	Directions: 1. Fill the glass pan with tap water. Let the pan rest for a few minutes while the water settles. 2. Place a rock in a plastic bag and fill the bag with hot water. Seal the bag, and use the clothespin to clip it to one corner of the glass pan. 3. Fill another bag with ice cubes or the chemical cold pack, and clip the bag to the opposite corner of the pan. 4. Use one of the droppers to add four drops of food coloring to the water next to the ice cube. 5. Use the other dropper to add four drops of a different color of food coloring next to the bag of hot water. Observe the food coloring for several minutes. ***Journal Write:*** 6. Draw a diagram of the simulation 7. Record your observations. A. Where are the oceans coldest? B. Where are they the warmest? C. Where did the water sink or downwell? D. Where did the water rise or upwell? 8. Describe the direction of the current flow. Based on JPL. Classroom activities. Visit to an Ocean Planet. *Temperature and Deep Ocean Circulation.* Available: http://topex-www.jpl.nasa.gov/education/activities.html
EXPLAIN	***Journal Write:*** 1. Could a similar process lead to the formation of deep ocean currents? 2. Predict where on the world map deep ocean currents form.

	3. What evidence will support this hypothesis? Provide students with maps of ocean temperatures showing surface temperatures and vertical distribution temperatures/ NASA. *Ocean Temperatures.* Available: http://icp.giss.nasa.gov/research/oceans/oceanchars/temperature.html 4. Examine the Ocean temperature maps. 5. Do these maps support your hypothesis for the formation of deep ocean currents? Cite evidence from the maps in your answer.
EXTEND	How do changes in salinity affect the formation of deep ocean currents? Show students a picture of sea ice. When icebergs and sea ice form, how does their formation affect the water surrounding them? Materials: two 500 mL beakers, salt water, freezer Teacher Note: Prior to class fill two 500mL beakers with equal amounts of salt water. Place one beaker in a freezer until a layer of ice forms. Teacher demonstration: 1. Show the students the beaker containing the non-frozen seawater. Using either a hydrometer or a salinity meter, determine the salinity. 2. Now show the beaker containing the layer of ice. 3. Break through the ice and measure the salinity of the saltwater. *It will be saltier than the first beaker. As saltwater freezes, most of the sea salt is extruded in order to form the crystalline structure of ice. The water directly under the ice becomes saltier and sinks.* <u>Adaptive Strategy</u>: Draw a hydrated ion and the molecular structure of ice. Show how ions must be forced out in order to form the crystalline structure.

	Journal Write: · What happens to water as the salinity increases? *It becomes unstable due to increased density and sinks. This creates areas of downwelling.* Provide students with a salinity profile diagram. For example, University Corporation for Atmospheric Research, University of Michigan. *Standard salinity profile.* Available: http://windows.arc.nasa.gov/tour/link=/earth/Water/salinity_depth.html&edu=high ***Journal Write:*** 1. What is the relationship between increasing salinity and the depth of the ocean water? *The saltier the water, the deeper it is.* 2. How can salinity changes that occur at the ocean's surface lead to the formation of deep ocean currents? Technical Connection: View the animation *Global Conveyor Belt.* JPL. (1998). Visit to an Ocean Planet CD-ROM *Global Conveyor Belt Animation.* Teacher Note: If your animation of the "Global Conveyor Belt" is not working, visit San José State University. Department of Geology. *Let's ride the global conveyor belt.* Available: http://geosun1.sjsu.edu/~dreed/onset/exer11/9.html or JPL. Ocean Surface Topography from Space. *Gallery- Videos.* Available: http://topex-www.jpl.nasa.gov/gallery/videos.html ***Journal Write:*** Explain how temperature and salinity changes cause deep ocean currents.

	INTEREST CENTER Tutorial on surface and deep ocean currents. San Jose State University. *Global Circulation and the California Current.* Available: http://geosun1.sjsu.edu/~dreed/onset/exer11/1.html
EVALUATE	***Journal Write:*** Explain the causes of deep ocean currents. Cite evidence from the laboratory investigations and oceanic data to support your answer.

Materials per lab group:

- Glass dish, approximately 9 x 13 x 3 inches
- Water
- Two small zip-lock bags
- Two clothes pins or small clamps
- Food coloring (2 different colors)
- Two eye droppers
- Rock
- Ice cubes or chemical cold pack

Teacher Demonstration

- Hydrometer
- Salinity meter
- Two beakers
- Salt water
- Freezer

Resources:

Woods Hole Oceanographic Institution. *A Primer on Ocean Currents.*

Available: http://www.whoi.edu/coastal-briefs/Coastal-Brief-94-05.html

Montana State University (using NASA data sets). *Dynamic Sea Surface Temperatures*. Available: http://www.math.montana.edu/~nmp/materials/ess/hydrosphere/advanced/adv_sea_temp/

JPL. Ocean Surface Topography from Space. *Gallery- Videos.* Available: http://topex-www.jpl.nasa.gov/gallery/videos.html

Glencoe McGraw-Hill. (2002). Earth Science: Geology, the Environment and the Universe. pp. 397-398.

San Jose State University. *Global Circulation and the California Current.* Available: http://geosun1.sjsu.edu/~dreed/onset/exer11/1.html

JPL. (1998). Visit to an Ocean Planet CD-ROM. "Temperature and Deep Ocean Circulation."

JPL. (1998). Visit to an Ocean Planet CD-ROM *Global Conveyor Belt Animation.*

San José State University. Department of Geology. *Let's ride the global conveyor belt.* Available: http://geosun1.sjsu.edu/~dreed/onset/exer11/9.html

JPL. Classroom activities. Visit to an Ocean Planet. *Temperature and Deep Ocean Circulation.* Available: http://topex-www.jpl.nasa.gov/education/activities.html

NASA. *Ocean Currents.* Available: http://seawifs.gsfc.nasa.gov/OCEAN_PLANET/HTML/oceanography_currents_1.html

NASA. *Ocean temperature.*

Available: http://icp.giss.nasa.gov/research/oceans/oceanchars/temperature.html

University Corporation for Atmospheric Research, University of Michigan. *Salinity.*

Available: http://windows.arc.nasa.gov/cgi-bin/tour.cgi?link=/earth/Water/salinity.html&cd=false&cdp=/windows3.html&art=ok&frp=/windows3.html&fr=f&sw=false&edu=high

Earth/Space Systems Science
Unit III: The Hydrosphere

Lesson 11: DENSITY DRIVEN VERTICAL OCEAN CURRENTS

Estimated Time: Two fifty-minute blocks

Indicator(s) Core Learning Goal 1:

1.2.7 The student will use relationships discovered in the lab to explain phenomena observed outside the laboratory.

1.4.2 The student will analyze data to make predictions, decisions, or draw conclusions.

1.5.4 The student will use tables, graphs, and displays to support arguments and claims in both written and oral communications.

1.6.1 The student will use ratio and proportion in appropriate situations to solve problems.

1.6.3 The student will express and/or compare small and large quantities using scientific notation and relative order of magnitude.

1.6.5 The student will judge the reasonableness of an answer.

Indicator(s) Core Learning Goal 2:

2.3.1 The student will describe how energy and matter transfer affect Earth systems.
Assessment limits: Oceanic circulation (density differences, daily and seasonal land/sea breezes, Coriolis effect.)

Student Outcome(s):

1. The student will be able to compare wind-driven and density-driven circulation by analyzing the results of laboratory investigations.
2. The student will be able to describe how differences in water density influence vertical ocean circulation by analyzing temperature and salinity diagrams.

WHAT DOES THE RESEARCH SAY?

Driven by sunlight and earth's internal heat, a variety of cycles connect and continually circulate energy and material through the components of the earth system. Together, these cycles establish the structure of the earth system and regulate earth's climate. In grades 9-12, students review the water cycle as a carrier of material, and deepen their understanding of this key cycle to see that it is also an important agent for energy transfer. National Research Council, *National Science Education Standards* (1996).

Weather (in the short run) and climate (in the long run) involve the transfer of energy in and out of the atmosphere. Solar radiation heats the land masses, oceans, and air. Transfer of heat energy at the boundaries between the atmosphere, the land masses, and the oceans results in layers of different temperatures and densities in both the ocean and atmosphere. The action of gravitational force on regions of different densities causes them to rise or fall—and such circulation, influenced by the rotation of the earth, produces winds and ocean currents.
AAAS, *Benchmarks for Science Literacy* (1993).

Brief Description:

Students work through a variety of modeling activities and then use the Temperature-Salinity (T-S) Diagram to predict the behavior of water masses.

Background knowledge / teacher notes:

Teacher note: Prior to class, prepare three very cold colored saltwater solutions parts per thousand [ppt]:

20 ppt – red 30 ppt – green 40 ppt – blue

Salinities do not need to be precise: low, medium and high salinity will work as well.

Students need enough salt water to form a layer covering the bottom of the container.

Lesson Description:

ENGAGE	Discussion: 1. What are the characteristics of wind-driven currents? 2. List these on the board or overhead. 3. Which characteristics can we observe in the lab? 4. How do we calculate the speed of a current? Directions: Using these materials large, clear container, warm tap water, drinking

	straw, cork stopper, stopwatch, ruler, design an experiment to observe the characteristics of wind driven currents. Materials per group of four: large, clear container, warm tap water, drinking straw, cork stopper, stopwatch, ruler Sample procedures: 1. Fill a large clear container with warm tap water. 2. Place a cork stopper at one side of the container. 3. Draw a picture of the tray and the starting location of the cork. 4. Start timing. Generate a wind-driven current to move the cork across the container. ***Journal Write:*** 5. On the diagram, trace the path the cork followed. 6. Record the number of seconds it takes the cork to travel across the container. 7. Calculate the speed of the current. <u>Adaptive Strategy:</u> To calculate the speed of a current, divide the distance the cork traveled by the number of seconds. Let students use a calculator. Each group shares their results with the class.
EXPLORE	***Journal Write***: Write a hypothesis predicting the characteristics of deep ocean currents. Teacher Note: Assign each lab group one of the following salinities: 20 ppt, 30 ppt, and 40 ppt. Salinities do not need to be precise; low, medium and high salinity will work. As a class, brainstorm procedures for determining the characteristics of density-driven or deep ocean currents.

	Density-Driven Currents Materials per group of four: large, clear container, warm tap water, stopwatch, beaker, colored salt water 20 ppt, 30 ppt, 40 ppt, ruler Sample Procedure: 1. Fill a large clear container with warm tap water. ***Journal Write:*** 2. Draw a diagram of the container. 3. Time the number of seconds it takes the salt water to travel from one side of the container to the other. 4. Slowly add the colored, very salty water to one side of the container. 5. Record the time it takes for the salt water to travel across the container. 6. On the diagram, trace the path of the current. 7. Calculate the speed of the current. Adaptive Strategy: Model how to pour the salt water to the container or the activity may be done as a class demonstration. To calculate the speed of a current, divide the distance the salt water traveled by the number of seconds. Record the speed of the currents on a class data table.
EXPLAIN	In small groups discuss: 1. Are there currents at the bottom of the ocean? 2. What causes the formation of deep ocean currents? 3. How do differences in salinity affect ocean currents? *The saltier the current, the faster it sank and the further it moved across the container*. 4. What can you conclude about the characteristics of deep ocean

	currents? *Slow moving, salty or very dense* 5. How does this conclusion compare with your hypothesis? ***Journal Write:*** Complete a graphic organizer comparing wind-driven and density-driven currents. Be sure to include the speed, geographical distribution, and type of movement, causes of the currents.
EXTEND	Read to be informed about deep ocean currents. Rice University. Oceans. *What does the water do below the surface?* Available: http://www.glacier.rice.edu/oceans/4_densitydriven.html Or Glencoe McGraw-Hill. (2002). Earth Science: Geology, the Environment and the Universe. pp. 397-398. Or other similar text passages. Adaptive Strategy: Prior to reading preview difficult terminology such as thermohaline or halocline ***Journal Write:*** 1. Create a graphic organizer of deep ocean currents characteristics. 2. Why do the deepest ocean currents form at the poles? 3. Trace the flow of the Antarctic Bottom Water and the North Atlantic Deep Water on a world map. Characteristics of Deep Water Masses Directions: 1. Record the following information in your journal. 2. Examine the Temperature-Salinity (T-S) Diagram. 3. Describe the relationship among temperature, salinity and density. 4. Make a data table to record the temperature, salinity and density of three water samples. Find the temperature and salinity for the two surface seawater samples labeled "A" and "B" and record these values in the table. 5. What are the densities for samples "A" and "B?" In the data table,

	record these values to the fourth decimal place. Teacher Note: Model how to use scientific notation. 6. Compare the densities of the two water samples. Part Two 7. If surface waters of the same density are brought together they tend to mix. The temperature and salinity of the new water sample are somewhere between the original temperatures and salinities. If equal volumes of samples "A" and "B" are mixed together, a new sample "C" will form. On the table, record the temperature and salinity of "C." (Hint: Mixing one liter of 10°C water with one liter of 30°C water produces two liters of water at 20°C.) 8. Plot the new sample "C" on the T-S Diagram. 9. According to the diagram, what is the density of sample "C?" Record this value in the table. 10. How does the density of sample "C" compare to the densities of "A" and "B?" 11. On the T-S Diagram, draw a straight line between points A and B. Any point on the straight line represents a possible mixture of these seawater samples, including sample "C." 12. Using the T-S Diagram, predict the density of any mixture of samples "A" and "B." 13. Compare the density of surface seawater samples "A" and "B" with the density of any resulting mixture of these original samples. 14. Predict whether this mixture will remain at the surface or sink into the ocean? Explain why the mixture will behave this way. <u>G/T Connection:</u> 15. Two water samples of different salinities and temperatures, but equal densities are mixed together. Based on this investigation, predict the density of the resulting mixture. Relate the behavior of

	this mixture to the layered circulation of ocean water. INTEREST CENTER NASA. *Climate change in Atlantic larger than previously thought.* Available: http://sse.jpl.nasa.gov/whatsnew/pr/010716G.html
EVALUATE	***Journal Write*** 1. Compare wind-driven and density-driven circulation. Use evidence from the laboratory investigations and technical readings to support your answer. 2. Describe how differences in water density may influence vertical ocean circulation. Refer to the temperature–salinity diagram in your answer.

Materials per lab group:

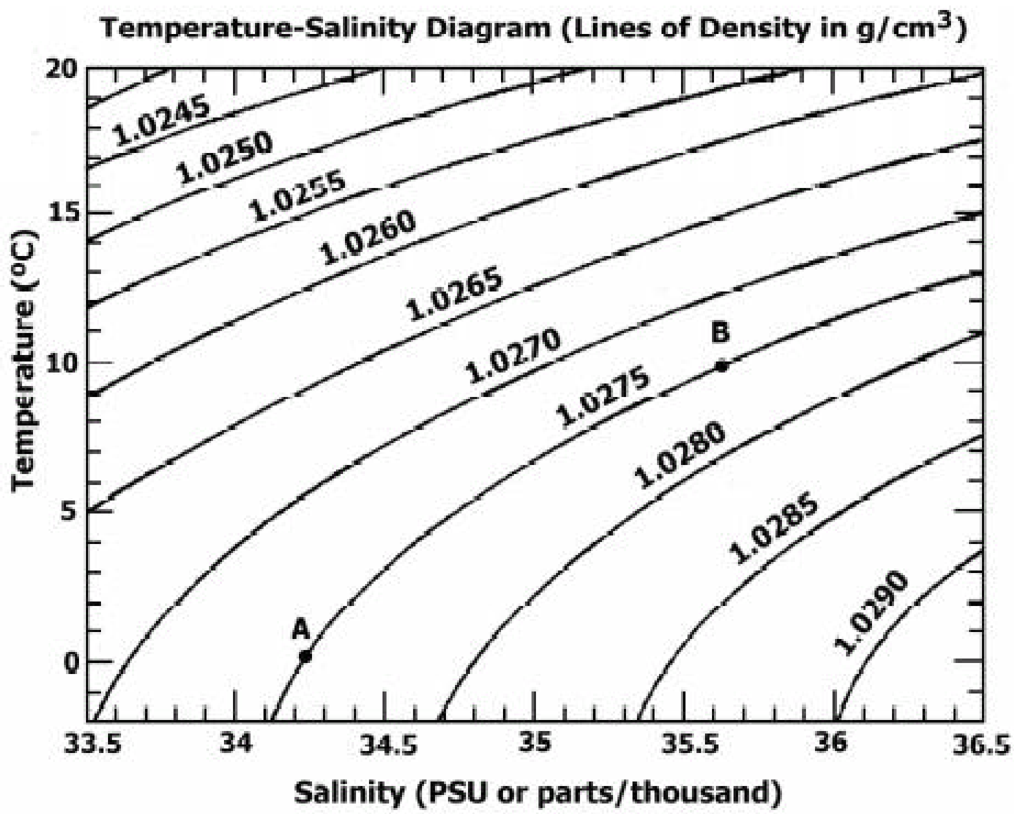
- Large clear container
- Drinking straw
- Salt water: 20 ppt, 30 ppt, 40 ppt
- Food coloring: red, green, and blue
- Cork stopper
- Stopwatch
- World map
- Temperature-Salinity Diagram

Characteristics of Deep Water Masses

Directions:

1. Record the following information in your journal.
2. Examine the Temperature-Salinity (T-S) Diagram.

Temperature is plotted along the vertical axis in degrees Celsius (°C). Salinity is measured along the horizontal axis in parts per thousand (‰) or numerically equal Practical Salinity Units (PSU).



2

Seawater density, in grams per cubic centimeter (g/cm^3), is shown on the diagram by curved lines of constant density. Each seawater sample is plotted as a dot (•) at the point determined by its temperature and salinity.

3. Describe the relationship among temperature, salinity and density.

4. Make a data table to record the temperature, salinity and density of three water samples. Find the temperature and salinity for the two surface seawater samples labeled “A” and “B” and record these values in the table.
5. What are the densities for samples “A” and “B?” In the data table, record these values to the fourth decimal place.
6. Compare the densities of the two water samples.

Part Two

7. If surface waters of the same density are brought together they tend to mix. The temperature and salinity of the new water sample are somewhere between the original temperatures and salinities. If equal volumes of samples “A” and “B” are mixed together, a new sample “C” will form. On the table, record the temperature and salinity of “C.” (Hint: Mixing one liter of 10°C water with one liter of 30°C water produces two liters of water at 20°C.)
8. Plot the new sample “C” on the T-S Diagram.
9. According to the diagram, what is the density of sample “C?” Record this value in the table.
10. How does the density of sample “C” compare to the densities of “A” and “B?”
11. On the T-S Diagram, draw a straight line between points A and B. Any point on the straight line represents a possible mixture of these seawater samples, including sample "C."
12. Using the T-S Diagram, predict the density of any mixture of samples “A” and “B.”

13. Compare the density of surface seawater samples “A” and “B” with the density of any resulting mixture of these original samples.
14. Predict whether this mixture will remain at the surface or sink into the ocean? Explain why the mixture will behave this way.

<u>G/T Connection:</u>

15. Two water samples of different salinities and temperatures, but equal densities are mixed together. Based on this investigation, predict the density of the resulting mixture. Relate the behavior of this mixture to the layered circulation of ocean water.

JPL. Classroom activities. Visit to an Ocean Planet. *Seawater Mixing and Sinking.*
Available: http://topex-www.jpl.nasa.gov/education/activities/ts2ssac3.pdf

Earth/Space Systems Science
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Resources:

NASA. *Climate change in Atlantic larger than previously thought.*
Available:
http://sse.jpl.nasa.gov/whatsnew/pr/010716G.html

Glencoe McGraw-Hill. (2002). Earth Science: Geology, the Environment and the Universe. pp. 397-398.

JPL. (1998). Visit to an Ocean Planet CD-ROM. "Seawater Mixing and Sinking"

JPL. Classroom activities. Visit to an Ocean Planet. *Seawater Mixing and Sinking.*
Available: http://topex-www.jpl.nasa.gov/education/activities/ts2ssac3.pdf

Prentice Hall. (1999). The Earth System. *The circulation of oceans*. pp. 79-96

Rice University. Oceans. *What does the water do below the surface?*
Available: http://www.glacier.rice.edu/oceans/4_densitydriven.html

Earth/Space Systems Science
Unit III: The Hydrosphere

Lesson 12: UPWELLING

Estimated Time: Two fifty-minute blocks

Indicator(s) Core Learning Goal 1:

1.2.3 The student will formulate a working hypothesis.

1.2.4 The student will test a working hypothesis.

1.41. The student will organize data appropriately using techniques such as tables, graphs, and webs. (for graphs: axes labeled with appropriate quantities, appropriate units on axes, axes labeled with appropriate intervals, independent and dependent variables on correct axes, appropriate title)

1.4.2 The student will analyze data to make predictions, decisions, or draw conclusions.

1.4.3 The student will use experimental data from various investigators to validate results.

1.4.6 The student will describe trends revealed by data.

Indicator(s) Core Learning Goal 2:

2.3.1 The student will describe how energy and matter transfer affect Earth systems. Assessment limits (at least) -Atmospheric circulation (heat transfer systems – conduction/convection/radiation, phase change, latent heat, pressure gradients, general global circulation, Coriolis effect). Oceanic circulation (density differences, daily and seasonal land/sea breezes, Coriolis effect)

2.3.2 The student will explain how global conditions are affected when natural and human-induced change alter the transfer of energy and matter. Assessment limits: Ocean-atmosphere-land interactions (current changes, continental movement, El Niño, La Niña)

Student Outcome(s):

The student will be able to describe the causes and effects of upwelling by analyzing the relationship among wind direction, Coriolis effect and sea surface temperatures.

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Unit III: The Hydrosphere

WHAT DOES THE RESEARCH SAY?

Transfer of heat energy at the boundaries between the atmosphere, the land masses, and the oceans results in layers of different temperatures and densities in both the ocean and atmosphere. The action of gravitational force on regions of different densities causes them to rise or fall—and such circulation, influenced by the rotation of the earth, produces winds and ocean currents. AAAS, *Benchmarks for Science Literacy* (1993).

Brief Description:

In this lesson, students explore upwelling as they analyze the relationship among, wind direction, sea surface temperatures and Coriolis effect.

Background knowledge / teacher notes:

Wind can generate vertical water motions in processes called upwelling. When wind blows over water, the surface water does not move directly in front of the wind, but moves about 45 degrees toward the right of the wind's motion in the Northern Hemisphere. This process is called Ekman transport and is a result of the Coriolis effect. In the Northern Hemisphere, surface water is deflected to the right of the wind's motion. Where winds cause the surface water to move away from a coastline, deeper water will move up to the ocean surface, creating an *upwelling* current. Winds moving from north to south cause surface water to move toward the west, away from the coastline. Upwelling currents are created, which bring deeper, colder water to the surface. Some coastal waters are cold because of these cold upwelling areas.

Surface waters are usually depleted of nutrients such as phosphates and nitrates that are critical to plant growth, but deeper waters have high concentrations of these nutrients. Upwelling replenishes the surface layers with the nutritional components necessary for biological productivity. Regions of upwelling are among the richest biological areas of the world. Modified from Department of Geosciences, San Francisco State University. *Upwelling Currents.* Available: http://squall.sfsu.edu/courses/geol103/labs/labs.html

Lesson Description:

<table>
<tr><td>ENGAGE</td><td>
Teacher Demonstration upwelling.
Materials: Very dense cold seawater (color with food coloring), clear fresh water, large clear container, hair dyer
Teacher Note: This demonstration may also be done using oil and fresh water. In this case, the fresh water will be on the bottom so color it blue.
Directions:
1. Pour colored seawater into a deep clear dish. This is the Pacific Ocean.
2. Cover with clear fresh water.
3. Using a hair dryer blow air over the surface waters from east to west. The hair dryer represents the trade winds.

As a class describe what happens as the trade winds blow over the water. The surface water is blown off and deep ocean water rises to the surface. This is called upwelling.

Discussion:
This phenomenon happens in the ocean as well.
1. Give students a diagram showing winds blowing parallel to the coast from north to south.
2. How do the winds and the Coriolis effect affect coastal circulation? Blow the surface layer of water off, letting the cooler denser water rise to the surface.
3. Predict where in the world will upwelling take place
<u>Technology Connection:</u>
View the upwelling video online.
</td></tr>
</table>

	NASA. Bigelow. Laboratory for Ocean Sciences. *Upwelling video.* Available: http://www.bigelow.org/foodweb/upwell.mov With your partner, brainstorm the characteristics of the deep water. *Cold, salty, dense, nutrient rich.* Discussion: How can we locate areas of upwelling? *Upwelling water can be tracked by measuring its cool temperature, high nutrient content, high salinity and high density*.
EXPLORE	Technology Connection: View the upwelling simulation Rutgers University. The Coolroom. *Life cycle of an upwelling event.* Available: http://marine.rutgers.edu/coolroom/education/upwelling.htm Adaptive Strategy: Read to be informed about upwelling. (See resources) JPL. (1998). Visit to an Ocean Planet CD-ROM. *Coastal Upwelling - Monterey Bay California* or the website. JPL. NASA. Classroom Activities. *Ocean Surface Topography from Space.* Available: http://topex-www.jpl.nasa.gov/education/activities/ts2siac6.pdf Or other similar text passages.
EXPLAIN	***Journal Write:*** 1. Diagram upwelling. Label the water layers Think-Pair-Share 2. What is the relationship between upwelling and the Coriolis effect? 3. Why does water temperature become stratified in the warmer months?

	4. What affect might this have on upwelling?
EXTEND	Directions: 1. Using a graphing program such as NCES. *Create a Graph*. Available: http://nces.ed.gov/nceskids/graphing/ or Excel, Graph sea surface temperatures in Monterey bay over time. (see resources) ***Journal Write:*** 1. Look at the graph. How do the sea surface temperatures change over time? 2. What might be causing these changes? 3. Using a graphing program such as NCES. *Create a Graph*. Available: http://nces.ed.gov/nceskids/graphing/ or Excel, to graph the wind speed and wind direction from buoy 46042 in the Monterey Bay, graph wind speed and time. Negative numbers indicate winds from the south. (See resources) ***Journal Write:*** 1. How do the winds speeds and wind direction change over time? 2. Examine the map of Monterey Bay, California is upwelling taking place? Support your answer using evidence from the map and your graphs. G/T Connection: Rice University. Glacier. *Oceans.* Available: http://www.glacier.rice.edu/oceans/4_upwelling.html ***Journal Write:*** What is the connection between upwelling and the productivity of the fishing industry? *Upwelling replenishes the surface water with the nutrients necessary to support oceanic food webs. Regions of upwelling are among the most productive fishing areas of the world.*

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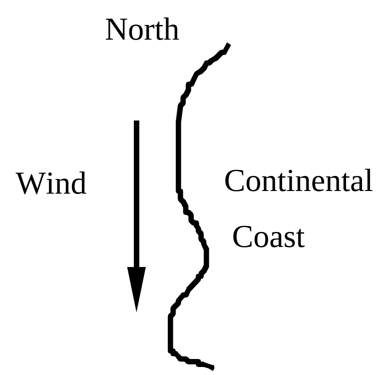
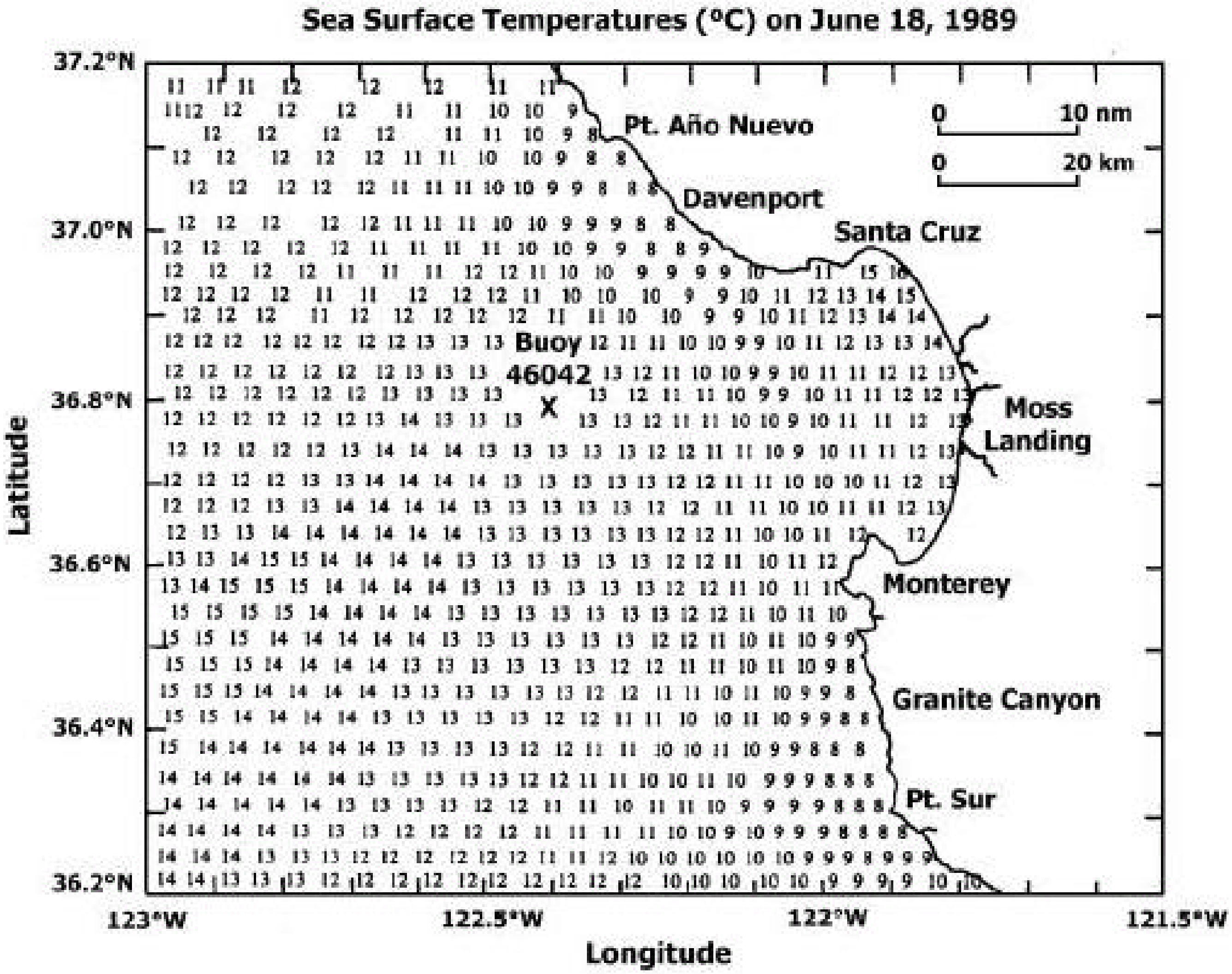
EVALUATE	***Journal Write:*** 1. What is the relationship among wind speed, wind direction and sea surface temperature? Use evidence from your graphs in your statement. 2. Why doesn't upwelling occur on the East Coast of the United States?

Materials:

- Deep clear pan
- Colored salt water
- Clear fresh water
- Hair dryer
- Map of sea surface temperatures
- Graph paper



Map of Coastal Waters of Monterey Bay, California



(Data from NOAA/TIROS-N satellite)

From JPL. (1998). Visit to an Ocean Planet CD-ROM. *Coastal Upwelling - Monterey Bay California* or the website. JPL.NASA. *Ocean Surface Topography from Space. Classroom Activities.* Available: http://topex-www.jpl.nasa.gov/education/activities/ts2siac6.pdf

Coastal Waters of Monterey Bay, California

Date	Sea Surface Temperature (°C)	Wind Direction	Wind Speed
May 23	10	N	3
May 25	10	N	8
May 27	9	N	10
May 29	9	N	8
May 31	9	N	4
June 2	10	S	-1
June 4	12	S	-4
June 6	13	S	-3
June 8	12	N	7
June 10	11	N	5
June 12	10	N	8
June 14	10	N	7
June 16	10	N	7
June 18	9	N	9
June 20	9	N	11
June 22	11	N	4
June 24	12	S	-4
June 26	13	S	-6
June 28	13	-	0
June 30	14	S	-1
July 2	13	N	6
July 4	11	N	9
July 6	9	N	10
July 8	9	N	10

From JPL. (1998). Visit to an Ocean Planet CD-ROM. *Coastal Upwelling - Monterey Bay California* or the website.

JPL.NASA. *Ocean Surface Topography from Space. Classroom Activities.*

Available: http://topex-www.jpl.nasa.gov/education/activities/ts2siac6.pdf

COASTAL UPWELLING - MONTEREY BAY CALIFORNIA

INTRODUCTION

Monterey (Study Area)

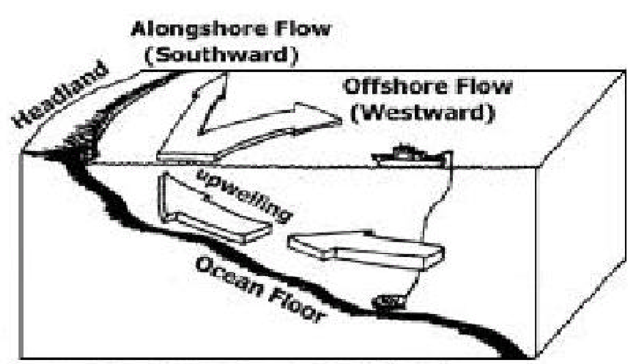
Coastal upwelling is the upward movement of water along a coast. This rising water is usually cooler and more nutrient rich than the surface water it replaces.

The upwelling of nutrient rich water has made Monterey Bay, on the central coast of California, a favorite with fishermen. This information is presented in a form that provides students with a clear picture of upwelling concepts.

Northwest winds: The strongest upwelling occurs when the Monterey area is experiencing winds from the northwest which blow parallel to the coast of California. When these winds are weak or the winds are from the south, the upwelling tends to stop and the warmer waters of the California current move into Monterey Bay. The very large California Current travels southward along the California coast from the North Pacific.

Headlands: Observations of sea surface temperature from satellites show that upwelling is not uniform along the central California coast, but is strongest at the major headlands. The cold water of Monterey Bay comes primarily from the upwelling in the Point Año Nuevo area, and then progresses south across the mouth of Monterey Bay toward the Monterey Peninsula.

Coriolis effect: In the northern hemisphere the rotation of Earth causes surface water to move to the right of the wind. This movement to the right is known as the Coriolis effect. In the Monterey area, winds out of the northwest cause water to flow to the southwest, away from the coast. The water flowing offshore is replaced by the cool, nutrient rich water which rises up into the coastal area from below, resulting in the upwelling phenomena.



Looking South from Point Año Nuevo toward Monterey Bay

Bifurcated flow: When cool upwelling water rises to the surface at the headlands it departs in two directions, one tending offshore (to the west) and the other toward the equator (south). The upwelled water that flows westward, away from the coast, is immediately influenced by the Coriolis effect. The portion of the upwelled water that is traveling south is influenced by the Coriolis effect, the geography of the coastline, winds from the northwest and the California current.

1

The upwelling water can be tracked by measuring its cool temperature, high nutrient content, high salinity and high density. The nutrients brought to the surface encourage the high plankton productivity of the Monterey Bay area which is why it is an excellent fishing locality.

From JPL. (1998). Visit to an Ocean Planet CD-ROM. *Coastal Upwelling - Monterey Bay California* or the website. JPL. NASA. Classroom Activities. *Ocean Surface Topography from Space.*

Available: http://topex-www.jpl.nasa.gov/education/activities/ts2siac6.pdf

Resources:

JPL.NASA. (1998). Visit to an Ocean Planet CD-ROM. *Coastal Upwelling - Monterey Bay California.*
Available: http://topex-www.jpl.nasa.gov/education/activities/ts2siac6.pdf

JPL. NASA. Classroom Activities. *Ocean Surface Topography from Space.*
Available: http://topex-www.jpl.nasa.gov/education/activities/ts2siac6.pdf

Rutgers University. The Coolroom. *Life cycle of an upwelling event.*
Available: http://marine.rutgers.edu/coolroom/education/upwelling.htm

Rice University. Glacier. *Oceans.*
Available: http://www.glacier.rice.edu/oceans/4_upwelling.html

Department of Geosciences, San Francisco State University. *Upwelling Currents.*
Available: http://squall.sfsu.edu/courses/geol103/labs/labs.html

NASA. Bigelow. Laboratory for Ocean Sciences. *Upwelling video.*
Available: http://www.bigelow.org/foodweb/upwell.mov

Earth/Space Systems Science
Unit III: The Hydrosphere

Lesson 13: THE GLOBAL CONVEYER BELT

Estimated Time: One fifty-minute block

Indicator(s) Core Learning Goal 1:

1.1.2 The student will modify or affirm scientific ideas according to accumulated evidence.

1.2.7 The student will use relationships discovered in the lab to explain phenomena observed outside the laboratory**.**

1.4.2 The student will analyze data to make predictions, decisions, or draw conclusions.

1.4.3 The student will use experimental data from various investigators to validate results.

Indicator(s) Core Learning Goal 2:

2.3.1 The student will describe how energy and matter transfer affect Earth systems. Assessment limits: Oceanic circulation (density differences, daily and seasonal land/sea breezes, Coriolis effect).

Student Outcome(s):

The student will be able to explain the influence of the global conveyor belt on climates by analyzing interaction between surface currents and deep ocean currents and creating a systems diagram.

WHAT DOES THE RESEARCH SAY?

Driven by sunlight and earth's internal heat, a variety of cycles connect and continually circulate energy and material through the components of the earth system. Together, these cycles establish the structure of the earth system and regulate earth's climate. In grades 9-12, students review the water cycle as a carrier of material, and deepen their understanding of this key cycle to see that it is also an important agent for energy transfer. National Research Council, *National Science Education Standards* (1996).

The global temperature has fluctuated within a relatively narrow range, one that has been narrow enough to enable life to survive and evolve for over three billion years. They come to understand that some of the small temperature fluctuations have produced what we perceive as dramatic effects in the earth system, such as the ice ages and the extinction of entire species. They explore the regulation of earth's global temperature by the water and carbon cycles. Using this background, students can examine environmental changes occurring today and make predictions about future temperature fluctuations in the earth system. National Research Council, *National Science Education Standards* (1996).

Brief Description:

In this lesson, students synthesize their knowledge of surface and deep ocean currents into the global conveyor belt. After examining the movement of a water mass through the global conveyor belt, students discuss the influence of the global conveyor belt on climates.

Background knowledge / teacher notes:

From JPL. NASA. Visit to an Ocean Planet. Classroom activities. *Convection.*

Available: http://topex-www.jpl.nasa.gov/education/activities/ts1enac3.pdf

EXTENSION

Oceans lose heat off Greenland and in the Weddell Sea. As they lose heat, the surface waters become more dense, and they may become so dense during winter that the water sinks to the bottom. This convec-

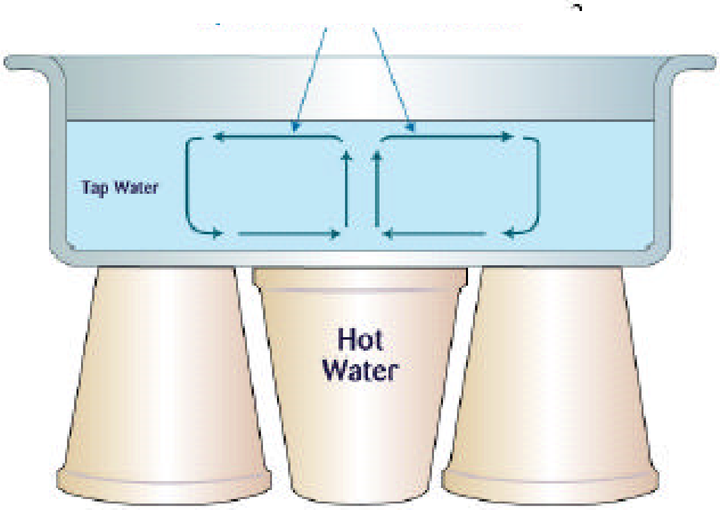


Figure 2. **Direction of water flow during the activity.**

ocean which also drives horizontal circulation, similar to that set up in the lab activity. For Earth, the net result is a transfer of heat from the equatorial regions to the polar regions. This mechanism, known as the *global conveyor belt,* is very important to regulating climate on Earth (see *Climate - Scale and Structure* and *Climate - Systems and Interactions* and the activities listed below for more information).

Convection is also an extremely important mechanism in the atmosphere, constantly affecting weather and climate through the redistribution of energy. One of the most common examples of atmospheric convection occurs when the Sun heats Earth's surface, which in turn heats the atmosphere above it. As the lower atmosphere heats up, it moves heat upwards by convection. This process can produce winds on a local or even global scale. In the tropics, hot moist air rises over the ocean and drives vigorous atmospheric circulation. Can the students postulate what types of atmospheric disturbances might result from such convection? Have any of the students seen satellite images of cloud cover in the tropical Pacific? Is this area usually cloudy or cloud-free? Would they expect to encounter thunderstorms during a vacation to the tropics? Why or why not?

Teacher note: Make the colored disks prior to class using a hole puncher and construction paper**.**

Lesson Description:

ENGAGE	Think-Pair-Share How does ocean circulation influence climate? Read to be informed about how do oceans transport heat JPL. NASA. *How the oceans transport heat.* (see resources) Available: http://topex-www.jpl.nasa.gov/education/images/oc_heat.gif Or other similar text passages. Think-Pair-Share 1. Examine the global conveyor belt diagram. What happens to the water that sinks in the polar regions? *Ultimately, these waters must return to the surface to complete the circulation. Thus if water is sinking (downwelling) at the high latitudes it must be rising (upwelling) somewhere else.*
EXPLORE	How do ocean currents transport heat? Have students perform the following laboratory investigation: Ocean Circulation Materials per group: l000 mL beaker, colored paper disks or other items that will, water, ring stand, ring clamp, wire mesh, Bunsen burner, ice cube Directions: 1. Fill a 1000 mL beaker to the 500 mL line with tap water. 2. Add ten colored paper disks to the beaker. 3. Set up a ring stand with a ring clamp and a wire mesh pad on the ring. 4. Place the beaker on the ring stand.

	5. Add a few ice cubes to the beaker. 6. Center a Bunsen burner under the beaker. Light the burner and heat the water to a full boil. 7. Observe the movement of the paper disks. Adaptive Strategy: This may also be done as a teacher demonstration. ***Journal Write:*** 8. Draw a diagram of the experimental set up. 9. On your diagram, trace the pattern of the disks. 10. The pattern of the disks illustrates the movement of the water. Explain how and why the water moves. 11. What is the name of this circular movement of water? *convection cell*
EXPLAIN	***Journal Write:*** 1. Look at the diagram showing the temperatures of the Gulf Stream. Earth Observatory. NASA. *Temperature of the Gulf Stream.* Available: http://earthobservatory.nasa.gov/Newsroom/NewImages/images.php3?img_id=3975 The Gulf Stream transport heat from the equator to the poles on the surface, but how does it affect deep ocean circulation? 2. Based on this investigation, describe the interaction between surface and deep ocean currents.
EXTEND	Technology Connection: View the animation entitled "Global Conveyor Belt" to determine areas of rising deep ocean currents (upwelling). JPL. (1998). Visit to an Ocean Planet CD-ROM. "Global Conveyor Belt animation." Teacher Note: If your animation of the "Global Conveyor Belt" is not working, visit San José State University. Department of Geology.

	Let's ride the global conveyor belt. Available: http://geosun1.sjsu.edu/~dreed/onset/exer11/9.html or JPL. Ocean Surface Topography from Space. *Gallery- Videos.* Available: http://topex-www.jpl.nasa.gov/gallery/videos.html Adaptive Strategy: The website offers a very simple description of the interaction between surface and deep ocean currents as well as a clear explanation of how the global conveyor belt transports heat. San José State University. Department of Geology. *Let's ride the global conveyor belt.* Available: http://geosun1.sjsu.edu/~dreed/onset/exer11/9.html Provide students with a diagram the global conveyor belt. ***Journal Write:*** 1. Using colored pencils, indicate the warm currents and cold ocean currents. 2. Follow a water mass through the global conveyor belt describing its temperature, speed and location as it moves along the belt. Adaptive Strategy: Provide students with a sequence chart or other graphic organizer. 3. How does the Global Conveyor belt influence climate? G/T Connection: ***Journal Write:*** Suppose the global conveyor belt were to stop. Hypothesize the effects upon world climate. Use evidence from your investigations and discussions to support your answer.
EVALUATE	***Journal Write*:**

	1. Explain the influence of the global conveyor belt on climates around the world. 2. Create a systems diagram to illustrate your explanation of global conveyor belt.

Materials per group:

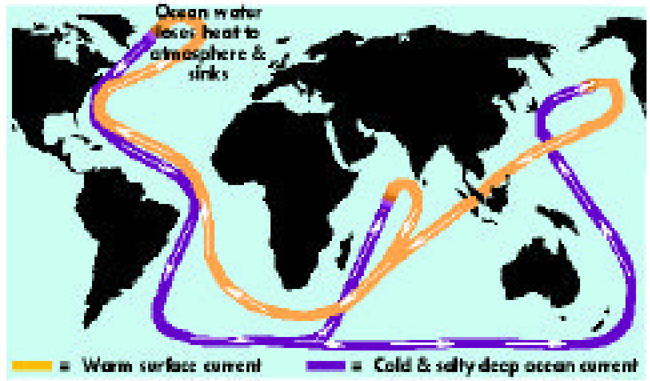
- Beaker, 1000 mL
- Ring stand
- Clamp
- Wire mesh pad
- Bunsen burner
- Ten colored-paper disks
- Ice cubes
- Diagram of Global Conveyor Belt
- Colored pencils

How the oceans transport heat

A global "conveyor belt" shows how ocean water loses heat in the North Atlantic, sinks, moves south, circulates around Antarctica, and then moves northward into the ocean basins.

This "circuit" takes up to 1000 years to complete!

How well this "conveyer belt" transports heat around the world oceans controls global climate.



In general, warm surface currents flow from the tropics to higher latitudes, driven mainly by winds and the Earth's rotation. Fast, warm surface currents, like the Gulf Stream, are concentrated at the western boundary of ocean basins.

From JPL. NASA. *How the oceans transport heat.*

Available: http://topex-www.jpl.nasa.gov/education/images/oc_heat.gif

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Unit III: The Hydrosphere

Ocean Circulation

Materials per group: l000 mL beaker, colored paper disks, water, ring stand, ring clamp, wire mesh, Bunsen burner, ice cubes

Directions:

1. Fill a 1000 mL beaker to the 500 mL line with tap water.
2. Add ten colored paper disks to the beaker.
3. Set up a ring stand with a ring clamp and a wire mesh pad on the ring.
4. Place the beaker on the ring stand.
5. Add a few ice cubes to the beaker.
6. Center a Bunsen burner under the beaker. Light the burner and heat the water to a full boil.
7. Observe the movement of the paper disks.

Journal Write:

8. Draw a diagram of the experimental set up.
9. On your diagram, trace the pattern of the disks.
10. The pattern of the disks illustrates the movement of the water. Explain how and why the water moves.
11. What is the name of this circular movement of water?

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Resources:

JPL. NASA. *How the oceans transport heat.*
Available: http://topex-www.jpl.nasa.gov/education/images/oc_heat.gif

JPL. (1998). Visit to an Ocean Planet CD-ROM. *Convection*.

JPL. Ocean Surface Topography from Space. *Gallery- Videos.*
Available: http://topex-www.jpl.nasa.gov/gallery/videos.html

JPL. (1998). Visit to an Ocean Planet CD-ROM. "Global Conveyor Belt animation."

NASA. *Temperature of the Gulf Stream.*
Available:
http://earthobservatory.nasa.gov/Newsroom/NewImages/images.php3?img_id=3975JPL.

NASA. Visit to an Ocean Planet. Classroom activities. *Convection.*
Available: http://topex-www.jpl.nasa.gov/education/activities/ts1enac3.pdf

San José State University. Department of Geology. *Let's ride the global conveyor belt.*
Available:
http://geosun1.sjsu.edu/~dreed/onset/exer11/9.html

Earth/Space Systems Science
Unit III: The Hydrosphere

LESSON 14: CLIMATE, WEATHER AND SEASON VARIABILITY

Estimated Time: Two fifty-minute blocks

Indicator(s) Core Learning Goal 1:

1.2.3 The student will formulate a working hypothesis.

1.2.4 The student will test a working hypothesis.

1.2.7 The student will use relationships discovered in the lab to explain phenomena observed outside the laboratory.

1.7.6 The student will explain how development of scientific knowledge leads to the creation of new technology and how technological advances allow for additional scientific accomplishments.

Indicator(s) Core Learning Goal 2:

2.3.1 The student will describe how energy and matter transfer affect Earth systems. Assessment limits (at least) -Atmospheric circulation (heat transfer systems – conduction/convection/radiation, phase change, latent heat, pressure gradients, general global circulation, Coriolis effect)

2.3.2 The student will explain how global conditions are affected when natural and human-induced change alter the transfer of energy and matter. Assessment limits: Ocean-atmosphere land interactions (current changes, continental movement, El Nino, La Nina). Climate type and distribution (temperature and precipitation)

Student Outcome(s):

1. The student will be able to identify trends that signal a change in the climate by analyzing satellite imagery and examining long-term weather patterns.
2. The student will be able to determine how seasonal changes in solar radiation affect sea level heights by conducting a laboratory investigation and analyzing satellite imagery.

Earth/Space Systems Science
Unit III: The Hydrosphere

WHAT DOES THE RESEARCH SAY?

Weather (in the short run) and climate (in the long run) involve the transfer of energy in and out of the atmosphere. Solar radiation heats the land masses, oceans, and air. Transfer of heat energy at the boundaries between the atmosphere, the land masses, and the oceans results in layers of different temperatures and densities in both the ocean and atmosphere. The action of gravitational force on regions of different densities causes them to rise or fall—and such circulation, influenced by the rotation of the earth, produces winds and ocean currents. AAAS, *Benchmarks for Science Literacy* (1993).

Transformations of energy usually produce some energy in the form of heat, which spreads around by radiation or conduction into cooler places. Although just as much total energy remains, its being spread out more evenly means less can be done with it. AAAS, *Benchmarks for Science Literacy* (1993).

Brief Description:

In this lesson students review the differences between climate and weather. Focusing on the oceans, they examine the effect of seasonal variations in solar radiation on water temperature and sea level heights. The high heat capacity of water is illustrated as the oceans reflect the changes in seasons.

Background knowledge / teacher notes:

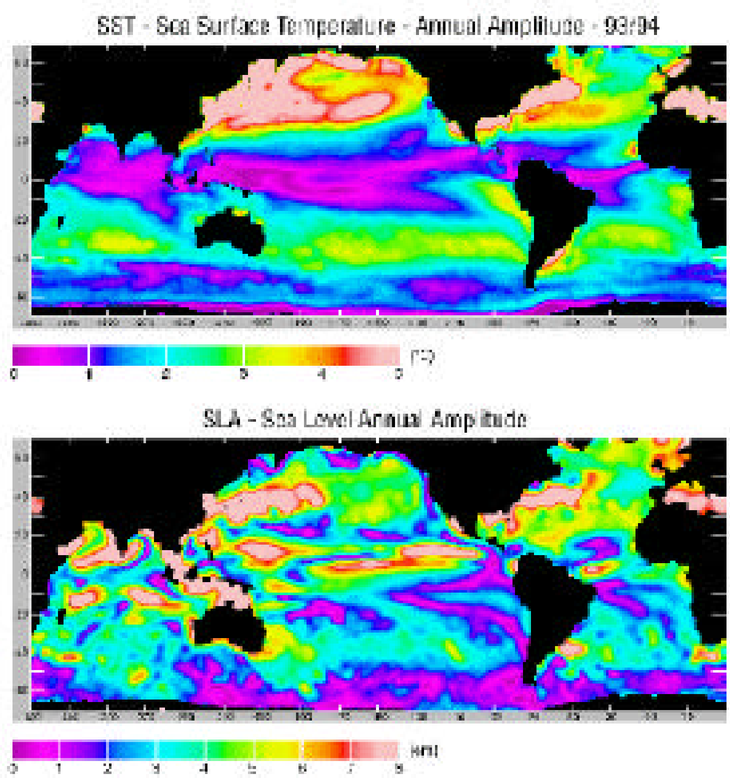
Weather is the current atmospheric conditions, including temperature, rainfall, wind, and humidity at any given place. If you stand outside, you can tell how hot it is by taking a temperature reading or feel if it is raining or windy, sunny or cloudy. All of these factors make up what we think of as weather. Weather is what is happening right now, or likely to happen tomorrow or in the very near future.

Climate, on the other hand, is the general weather conditions. For example, in the winter, we expect it to often be rainy in Portland, Oregon, sunny and mild in Phoenix, Arizona, and very cold and snowy in Buffalo, New York. But it would not be particularly startling to hear of an occasional January day with mild temperatures in Buffalo, rain in Phoenix, or snow in Portland. Meteorologists often point out that "climate is what you expect and weather is what you get." Or, as one student put it, "Climate helps you decide what clothes to buy, weather helps you decide what clothes to wear."

Adapted from the University Corporation for Atmospheric Research. *Differences between climate and weather.*

Available: http://www.ucar.edu/learn/1_2_2_8t.htm

Seasons and Oceans



The figure compares the sea level seasonal amplitude (or half-difference between summer maximum and winter minimum) in centimeters as observed by Topex/Poseidon in 1993-94 and R.W. Reynolds' temperature seasonal amplitude in degrees Celsius for the same period. Apart from the Tropics, the maps show interesting similarities. In particular, the maximum amplitudes appear between 30 and 50 degrees north and between 20 and 40 degrees south. These figures are on average higher in the northern hemisphere than the southern hemisphere because of the higher proportion of continental surface in the North. This reveals a relationship between temperature and large-scale sea level changes (the average ratio is close to 1 cm per degree).

From Aviso/Altimetry. *The Ocean Seasons.*

Available: http://www-aviso.cls.fr/html/applications/saisons/seasons_uk.html

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Lesson Description:

ENGAGE	Discussion: 1. How many of you check the weather forecast each day? 2. When you check the forecast, what information are you looking for? *Usually information about temperature and precipitation.* 3. Scientists agree they focus on temperature and precipitation when monitoring weather and climate. What's the difference between climate and weather? Working in pairs, students complete a Venn diagram comparing climate and weather. Discussion: 1. Each group shares its answers with the class. As a class, reach a consensus about the differences between climate and weather. 2. How do we monitor weather? *Weather stations across the country, satellites…* 3. What about the ocean weather? *Buoys, satellites,* 4. How can satellites monitor ocean temperatures?
EXPLORE	Have students work in small groups as they conduct this laboratory investigation. What happens to water as it's heated? From JPL. (1998). <u>Visit to an Ocean Planet</u>. CD-ROM. "Expansion of Water." Click on Climate, then Process and Change, and see Classroom activities. JPL. Classroom Activities. Visit to an Ocean Planet. *Expansion of Water.* Available: http://topex-www.jpl.nasa.gov/education/activities/ts1pcac2.pdf

	Materials: Erlenmeyer flasks, thermometer or temperature probe, hot plate, ruler, grease pencil Directions: 1. Hold a ruler vertically and measure 7 cm from the top of the flask. 2. With a grease pencil, mark a line 7cm from the top of the flask. 3. Fill the flask with cold water to just below the bottom of the neck. 4. Place the thermometer or temperature probe in the flask so that the bulb is submerged in the water. 5. Add or remove water so that with the thermometer in the bottle, the water level is at the 7 cm mark. 6. Heat the water to at least 80°C, but do not boil! 7. Monitor the temperature. Every time the temperature increases five degrees, measure the level of the water in the flask from the top. Record the temperature and water level in your data table. 8. Turn off the heat source if the water reaches to within one cm of the top. <u>Adaptive strategy</u>: chunk directions. Pair with a peer helper. <u>G/T Connection</u>: Calculate the volume change of the water that corresponds to the measured changes in height. This requires a good knowledge of the inner diameter of the bottle and its variations. For reference, the expected volume change from 20°C to 90°C is approximately 3.4%.
EXPLAIN	***Journal Write:*** 1. Graph the water level versus temperature. 2. Graph the change in water level versus temperature. 3. What is the relationship between water level and temperature? *Water expands about four percent when heated from room temperature to its boiling point.* 4. How can satellites use this information to monitor ocean

	temperatures? *The ocean expands when heated. Satellites can measure differences in sea level.* Show 3D pictures of sea level differences. PMEL/NOAA. TAO. *3D Animations of La Nina and El Nino.* Available: http://www.pmel.noaa.gov/tao/vis/explorer/t-dyn-med.html Or other similar animations showing sea level differences.
EXTEND	Have students brainstorm answers to the following question. How can we tell when the climate is changing? What information is required to signal a change in the climate? Technology Connection: Introduce seasons by viewing a short movie on the causes of seasons. JPL. (1998). Visit to an Ocean Planet. CD-ROM "Earth in its orbit and the relationship to seasons." Animation. Click on Ocean, then Process and Change, the Movies. or Bigelow Laboratory for Ocean Sciences. *Virtual Vacationland. Ocean Seasons. Earth in its orbit and the relationship to seasons*. Animation Available: http://www.bigelow.org/virtual/handson/seasons.mov Working in small groups, students analyze seasonal variation in ocean temperatures. Materials: four images of the global showing sea level heights, world map showing latitude/longitude lines From JPL. Classroom Activities. Visit to an Ocean Planet. *Ocean Seasons.* Available: http://topex-www.jpl.nasa.gov/education/activities/ts2pcac2.pdf Directions: 1. Locate the landmasses on each image. 2. Refer to the world map with latitude. On each of the images,

	sketch the equator and relevant latitude lines. 3. Starting with the first image, examine the area of the mid-latitudes in the northern hemisphere (20°N - 50°N). Refer to the color-coded sea surface height scale for the images. ***Journal Write:*** 4. In which image do you find the highest sea surface heights? 5. In which image do you find the lowest sea surface heights? Cite evidence from the images to support your answer. 6. Think of the four seasons (winter, spring, summer, fall) and the amount of solar radiation that occurs in each season. Use your sea surface height observations and hypothesize which of the four images represents sea levels during fall in the northern hemisphere (spring in the southern hemisphere)? Cite evidence to support your answer. *In the northern hemisphere fall, the temperature of the upper ocean layer and sea level are high after being warmed throughout the summer.* <u>Adaptive Strategy</u>: A clue for interpreting the images is that water has a very high heat capacity, meaning that it takes a lot of energy transfer to change its temperature, i.e., heat it up or cool it down. Thus, the ocean heats and cools more slowly than land. Help students use this concept, and their knowledge of the amount of solar heating that occurs in each season, to determine which map is from fall, winter, spring, and summer. 7. Suggest reasons for the seasonal sea level variations relate to the heat capacity of water? 8. Once you have determined which image represents fall in the northern hemisphere, locate the image that represents summer. ***Journal Write:*** 9. Which image represents summer? Cite evidence to support your answer.

	10. Compare sea surface heights between summer and fall? *The lowest sea levels occur in the northern hemisphere's spring.* G/T Connection: 11. Which maps represent the northern hemisphere in the winter and spring? Use evidence to explain your reasoning. 12. Compare sea level responses in mid-latitudes in the northern hemisphere with those in the southern hemisphere. Do they vary in the same way? *The southern hemisphere experiences seasonal changes, but to a lesser extent.* 13. Which hemisphere has larger variations in sea surface height? *Northern Hemisphere.* Suggest reasons what causes this difference. *One reason for this is that there is less land in the southern hemisphere. This limits the extent of cold winter air that blows out from continents to cool the oceans. Moreover, the southern hemisphere has a greater proportion of ocean to land, which results in a more moderate climate with less seasonal change.* Each group takes a turn presenting their hypotheses and evidence to class. Teacher Note: Through class discussion help the students understand that the high heat capacity of water is what leads to the changes in sea level. *Regional sea levels vary with the seasons. At mid-latitudes, 20° to 50° north and south, heating and cooling in the upper ocean controls sea level change (which causes higher sea levels due to thermal expansion of the water).* Are seasonal changes discernable on land? What's the climate like in Anne Arundel County? NOAA. *Selection Criteria for Displaying Period of Record.* Available:

	http://lwf.ncdc.noaa.gov/oa/climate/onlineprod/drought/xmgrg3.html 1. Select Maryland from the scroll list in “Select the State” or click on “List of State/Division maps” and choose Maryland. 2. Click on the List of State/Division maps that are available or Select Maryland from the scroll list in “Select the State”. 3. In the “Select the division number” section, select #4 (Anne Arundel County). 4. "Select the Parameter: choose "temperature" then go down to " Generate Graph." 5. Scroll to the bottom of the graphs and click on “Download the Data File.” ***Journal Write:*** 6. Describe the pattern illustrated on the graphs. 7. Is the seasonal variation evident on the graphs? Use data from the graphs to support your answer.
EVALUATE	***Journal Write:*** 1. In order to look for long-term changes in climate, what factors must scientists keep in mind? *There is variability in the yearly data due to seasons as well as temperature and precipitation fluctuations. In order to determine a actual change in climate, trends must be above or below the norms and continue for many years.* 2. Describe the effects of seasonal solar radiation on sea level heights. Cite evidence from the images to support your answer.

Materials per lab group:

- Four images of the global showing sea level heights
- World map showing latitude/longitude lines

Earth/Space Systems Science
Unit III: The Hydrosphere

Seasonal Variation in Ocean Temperatures

Directions:

1. Locate the landmasses on each image.
2. Refer to the world map with latitude. On each of the images sketch the equator and relevant latitude lines.
3. Starting with the first image, examine the area of the mid-latitudes in the northern hemisphere (20°N - 50°N). Refer to the color-coded sea surface height scale for the images.

Journal Write:

4. In which image do you find the highest sea surface heights?
5. In which image do you find the lowest sea surface heights? Cite evidence from the images to support your answer.
6. Think of the four seasons (winter, spring, summer, fall) and the amount of solar radiation that occurs in each season. Use your sea surface height observations and hypothesize which of the four images represents sea levels during fall in the northern hemisphere (spring in the southern hemisphere)? Cite evidence to support your answer.
7. Suggest reasons for the seasonal sea level variations relate to the heat capacity of water?
8. Once you have determined which image represents fall in the northern hemisphere, locate the image that represents summer.

Journal Write:

9. Which image represents summer? Cite evidence to support your answer.
10. How does sea surface height compare between summer and fall?

<u>G/T Connection:</u>

11. Which maps represent the northern hemisphere in the winter and spring? Use evidence to explain your reasoning.
12. Compare sea level responses in mid-latitudes in the northern hemisphere with those in the southern hemisphere. Do they vary in the same way?
13. Which hemisphere has larger variations in sea surface height?

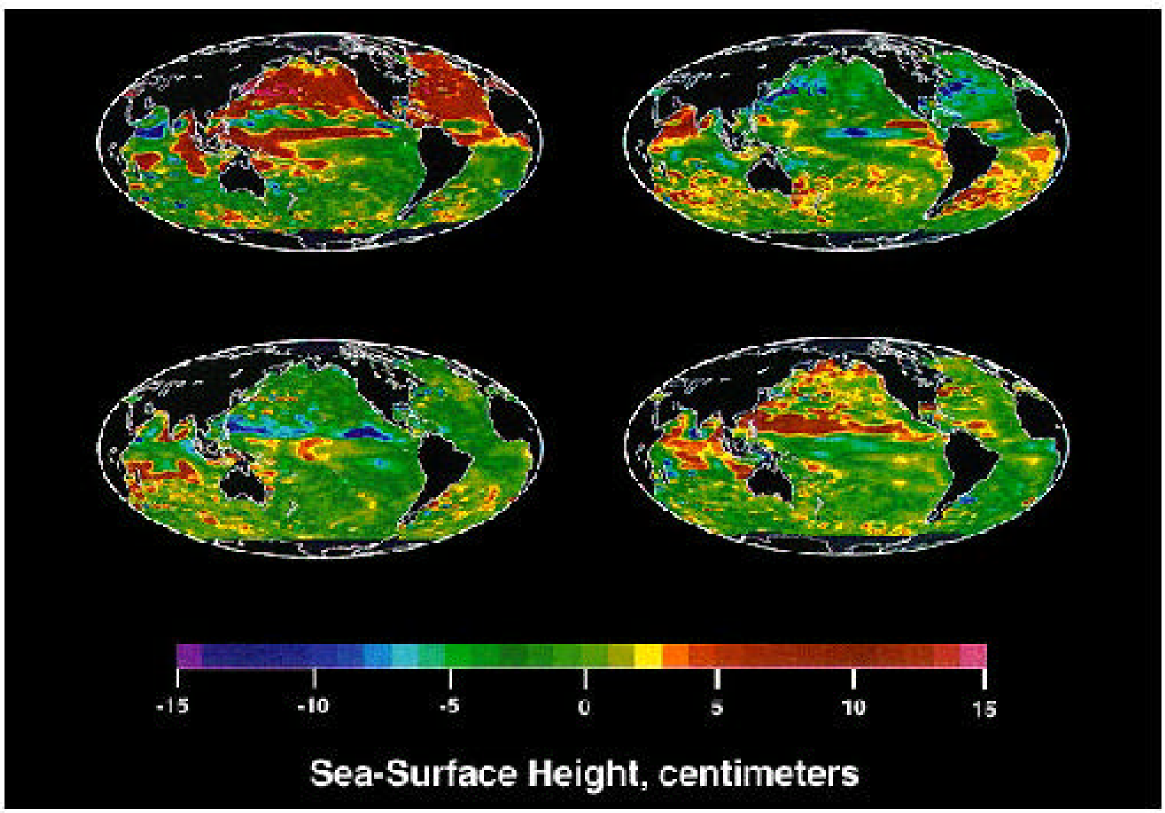


Figure 1. **Ocean seasons as measured by TOPEX/Poseidon.** The maps show variations in sea level relative to the ocean's annual average height. Each image corresponds to a different season. Effects of tides and gravity variations have been removed. The sea surface height scale is provided on the image.

2

From JPL. Classroom Activities. Visit to an Ocean Planet. *Ocean Seasons.*

Available: http://topex-www.jpl.nasa.gov/education/activities/ts2pcac2.pdf

Resources:

Aviso/Altimetry. *The Ocean Seasons.*
Available: http://www-aviso.cls.fr/html/applications/saisons/seasons_uk.html

Bigelow Laboratory for Ocean Sciences. *Virtual Vacationland. Ocean Seasons. Earth in its orbit and the relationship to seasons*. Animation
Available: http://www.bigelow.org/virtual/handson/seasons.mov

JPL. Classroom Activities. Visit to an Ocean Planet. *Expansion of Water.*
Available: http://topex-www.jpl.nasa.gov/education/activities/ts1pcac2.pdf

JPL. (1998). Visit to an Ocean Planet. CD-ROM "Expansion of Water."

JPL. (1998). Visit to an Ocean Planet. CD-ROM "Ocean Seasons."

JPL. (1998). Visit to an Ocean Planet. CD-ROM "Earth in its orbit and the relationship to seasons." Animation

JPL. Classroom Activities. Visit to an Ocean Planet. *Ocean Seasons.*
Available: http://topex-www.jpl.nasa.gov/education/activities/ts2pcac2.pdf

PMEL/NOAA. TAO. *3D Animations of La Nina and El Nino.*
Available: http://www.pmel.noaa.gov/tao/vis/explorer/t-dyn-med.html

Earth/Space Systems Science
Unit III: The Hydrosphere

Lesson 15: EL NINO/LA NINA

Estimated Time: Two fifty-minute blocks

Indicator(s) Core Learning Goal 1:

1.1.2 The student will modify or affirm scientific ideas according to accumulated evidence.

1.2.1 The student will identify meaningful, answerable scientific questions.

1.2.2 The student will pose meaningful, answerable scientific questions.

1.5.6 The student will read a technical selection and interpret it appropriately.

1.6.3 The student will express and/or compare small and large quantities using scientific notation and relative order of magnitude.

Indicator(s) Core Learning Goal 2:

2.3.2 The student will explain how global conditions are affected when natural and human-induced change alter the transfer of energy and matter. Assessment limits: Ocean-atmosphere-land interactions (current changes, continental movement, El Niño, La Niña)

Student Outcome(s):

The student will be able to describe the causes and effects of El Niño/Southern Oscillation by reading technical selections and analyzing data.

WHAT DOES THE RESEARCH SAY?

Weather (in the short run) and climate (in the long run) involve the transfer of energy in and out of the atmosphere. Solar radiation heats the land masses, oceans, and air. Transfer of heat energy at the boundaries between the atmosphere, the land masses, and the oceans results in layers of different temperatures and densities in both the ocean and atmosphere. The action of gravitational force on regions of different densities causes them to rise or fall—and such circulation, influenced by the rotation of the earth, produces winds and ocean currents.
AAAS, *Benchmarks for Science Literacy* (1993).

Earth/Space Systems Science
Unit III: The Hydrosphere

Brief Description:

During this lesson students discover the causes and effects of El Niño by examining satellite images and reading technical selections. The effects of El Niño on climate will be revisited during the unit on the biosphere.

Background knowledge / teacher notes:

For a detailed explanation of El Niño see NOAA/PMEL/TAO. *What is El Niño?*
Available: http://www.pmel.noaa.gov/tao/elnino/el-nino-story.html

Lesson Description:

ENGAGE	Read the following account out loud to the class. National Geographic Magazine Article. *El* Niño */La Niña Nature's Vicious Cycle Part 1.* Available: http://www.nationalgeographic.com/elnino/mainpage.html Or other similar text passages that discuss the global effects of El Niño. <u>Adaptive Strategy</u>: Have students record the problems mentioned in the article in a graphic organizer. Discussion: 1. What are some of the problems discussed in the article? *Abnormal rain and flooding, droughts, high temperatures, cyclones, forest fires* 2. Where are these problems occurring? *Around the world* 3. What does that indicate about the cause of the problems? *A global phenomena* 4. What do scientists think is the cause of these massive shifts in weather patterns? *El Niño*
EXPLORE	As a small group, list questions you have about El Niño. For example: What is El Niño? How can El Niño take over global weather patterns?

	Technology Connection: Working in small groups student analyze the symptoms of El Niño. NOVA Online Adventure. *Tracking El Niño Warm Water.* Available: http://www.pbs.org/wgbh/nova/elnino/anatomy/warmwater.html Directions: 1. Observe the entire animation of an El Niño event. 2. Restart the animation, click on the right arrow on the right side to and watch the changes week by week. ***Journal Write:*** 3. In Jan 97 is upwelling occurring off the coast of Peru? Give evidence to support your answer. *Yes the blue colors indicate cool waters in that area.* 4. During Jan 97 – Feb 97 is upwelling occurring off the coast of Peru? Give evidence to support your answer. *No the blue colors are gone, warm waters have invaded the area.* 5. Describe the pattern of ocean temperatures during Mar 97-Oct 97. Adaptive Strategy: Have students work with analyzing simple ocean diagrams first. Diagrams and instructions are located at JPL. Visit to an Ocean Planet. *Classroom Activities. El Niño Analysis.* Available: http://topex-www.jpl.nasa.gov/education/activities/ts2pcac3.pdf Or JPL (1998) Visit to an Ocean Planet CD-ROM "El Niño Analysis." Technology Connection: NOVA Online Adventure. *Tracking El Niño. Origins-Ground Zero*. Available: http://www.pbs.org/wgbh/nova/elnino/anatomy/origins.html Teacher Note: Help students orient themselves to the graphic. Point out the coastlines of Australia and Peru. Also, point out the thermocline and differences in the surface temperature.

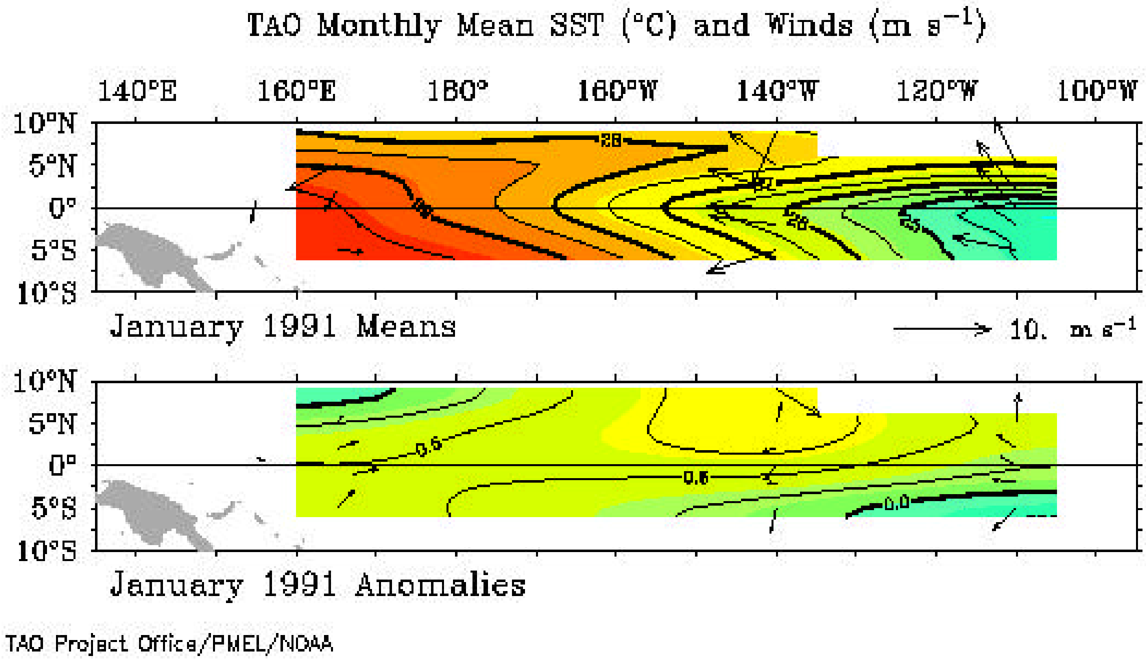
	Discussion: 1. What does this pattern of surface temperatures indicate? *El Niño* 2. Describe the appearance of the thermocline in the diagram. Run the animation several times. 3. Describe the changes in surface temperatures during the animation. 4. What is the relationship between the surface temperatures and the height of the thermocline?
EXPLAIN	***Journal Write:*** What are the symptoms of an El Niño event? Use evidence from the satellite data and animations to support your answer.
EXTEND	Read to be informed about the causes of El Niño/Southern Oscillation. National Geographic Magazine Article. *El Niño /La Niña Nature's Vicious Cycle Part 2.* Available: http://www.nationalgeographic.com/elnino/mainpage2.html Or other similar text passages. Adaptive Strategy: Have students read the following two articles instead. NASA. SAIC. *El Niño Making Sense of the Weather Normal Conditions.* Available: http://kids.earth.nasa.gov/archive/nino/normal.html NASA. SAIC. *El Niño Making Sense of the Weather El Niño Conditions.* Available: http://kids.earth.nasa.gov/archive/nino/elnino.html ***Journal Write:*** Create a graphic organizer such as a sequence chain, to record the causes of El Niño. Working in pairs, students analyze ocean data Examine the following maps of sea surface temperatures, wind speed

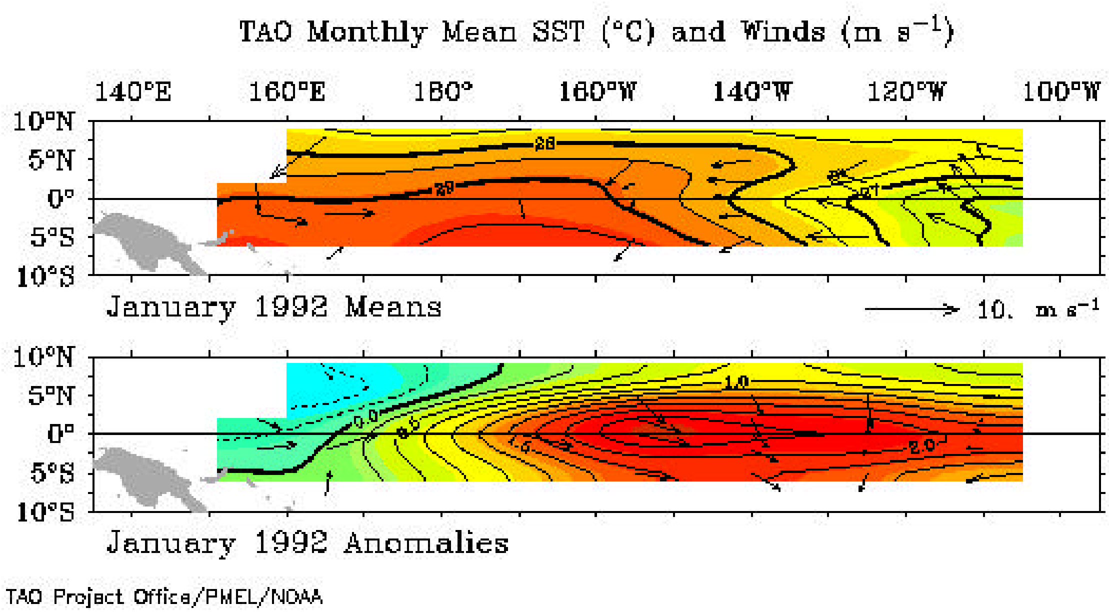
	and wind direction. ***Journal Write:*** 1. What event is shown in the January 1991 map? Cite evidence from the map to support your answer. *Upwelling* 2. What event is shown in the January 1992 map? Cite evidence from the map to support your answer. *El Niño* 3. What is taking place in the Pacific Ocean today? Visit TAO. *TAO/TRITON data display Sea Surface Temperatures and Winds.* Available: http://www.pmel.noaa.gov/tao/jsdisplay/ to download a map of today's conditions. Technical Reading: What happens when El Niño ends? Read about the characteristics of La Niña. National Geographic Magazine Article. *El Niño/La Niña Nature's Vicious Cycle Part 3.* Available: http://www.nationalgeographic.com/elnino/mainpage3.html Or other similar text passages. G/T Connection: NOAA/PMEL/TAO. *What is La Niña?* Available: http://www.pmel.noaa.gov/tao/elnino/la-nina-story.html#impact ***Journal Write:*** 1. Describe what La Niña is. 2. Why is it difficult to forecast El Niño/La Niña events? Discussion: What are the differences between El Niño and La Niña? Show students the three diagrams PMEL/NOAA. *El Niño Theme Page.* Available: http://www.pmel.noaa.gov/tao/elnino/nino_profiles.html The first diagram shows normal conditions, the second shows El Niño

	and the third, the beginning of La Niña Conditions. Multicultural Connection: Explore the effects of El Niño in different parts of the world. NOVA Online Adventure. *El Niño's Reach Across the Globe.* Available: http://www.pbs.org/wgbh/nova/elnino/reach/# INTEREST CENTER Center for Ocean-Atmospheric Studies. *El Niño Cartoons.* Available: http://www.coaps.fsu.edu/lib/climatoons/toon04.shtml
EVALUATE	***Journal Write:*** 1. What are the causes or symptoms of El Niño/Southern Oscillation? Cite evidence from your reading and data analysis to support your answer. 2. Describe some of the effects of El Niño/Southern Oscillation. 3. How does El Niño differ from La Niña? Cite evidence from your reading and data analysis to support your answer.

Materials:

Maps of sea surface temperatures, wind speed and wind direction


TAO Monthly Mean SST (°C) and Winds (m s⁻¹)
140°E 160°E 180° 160°W 140°W 120°W 100°W
10°N 5°N 0° 5°S 10°S
28
January 1991 Means
10. m s⁻¹
0.5
0.0
January 1991 Anomalies
TAO Project Office/PMEL/NOAA


TAO Monthly Mean SST (°C) and Winds (m s⁻¹)
140°E 160°E 180° 160°W 140°W 120°W 100°W
10°N 5°N 0° 5°S 10°S
28
29
27
January 1992 Means
10. m s⁻¹
1.0
0.0
0.5
1.5
2.0
January 1992 Anomalies
TAO Project Office/PMEL/NOAA

Resources:

JPL. Visit to an Ocean Planet. *Classroom Activities. El Nino Analysis.*
Available: http://topex-www.jpl.nasa.gov/education/activities/ts2pcac3.pdf

JPL (1998) Visit to an Ocean Planet CD-ROM "El Nino Analysis."

NOVA Online Adventure. *El Nino's Reach Across the Globe.*
Available: http://www.pbs.org/wgbh/nova/elnino/reach/#

National Geographic Magazine Article. *El Nino/La Nina Nature's Vicious Cycle Part 1*.
Available: http://www.nationalgeographic.com/elnino/mainpage.html

National Geographic Magazine Article. *El Nino/La Nina Nature's Vicious Cycle Part 2*.
Available: http://www.nationalgeographic.com/elnino/mainpage2.html

National Geographic Magazine Article. *El Nino/La Nina Nature's Vicious Cycle Part 3*.
Available: http://www.nationalgeographic.com/elnino/mainpage3.html

NASA. SAIC. *El Nino Making Sense of the Weather El Nino Conditions.*
Available: http://kids.earth.nasa.gov/archive/nino/elnino.html

NASA. SAIC. *El Nino Making Sense of the Weather Normal Conditions.*
Available: http://kids.earth.nasa.gov/archive/nino/normal.html

NOAA/PMEL/TAO. *What is El Nino?*
Available: http://www.pmel.noaa.gov/tao/elnino/el-nino-story.html

NOAA/PMEL/TAO. *What is La Nina?*
Available: http://www.pmel.noaa.gov/tao/elnino/la-nina-story.html#impact

PBS. NOVA Online Adventure. *Tracking El Nino. Origins-Ground Zero*.

Available: http://www.pbs.org/wgbh/nova/elnino/anatomy/origins.html

PBS. NOVA Online Adventure. *Tracking El Nino Warm Water.*

Available: http://www.pbs.org/wgbh/nova/elnino/anatomy/warmwater.html

PMEL/NOAA. *El Nino Theme Page.*

Available: http://www.pmel.noaa.gov/tao/elnino/nino_profiles.html

TAO. *TAO/TRITON data display Sea Surface Temperatures and Winds.*

Available: http://www.pmel.noaa.gov/tao/jsdisplay/

INTEREST CENTER

Center for Ocean-Atmospheric Studies. *El Nino Cartoons.*

Available: http://www.coaps.fsu.edu/lib/climatoons/toon04.shtml

Earth/Space Systems Science
Unit III: The Hydrosphere

Lesson A: **STRUCTURE OF THE HYDROSPHERE** **SUPPLEMENTAL LESSON**

Estimated Time: Two fifty- minute blocks

Indicator(s) Core Learning Goal 1:

1.4.6 The student will describe trends revealed by data.

1.4.9 The student will use analyzed data to confirm, modify, or reject a hypothesis.

Indicator(s) Core Learning Goal 2:

2.3.1 The student will describe how energy and matter transfer affect Earth systems. Assessment limits (at least) – Atmospheric circulation (heat transfer systems – conduction/convection/radiation, phase change, latent heat, pressure gradients, general global circulation, Coriolis effect). Oceanic circulation (density differences, daily and seasonal land/sea breezes, Coriolis effect)

Student Outcome(s):

The student will be able to describe the structure of the hydrosphere quantitatively by analyzing the reservoirs and fluxes.

Brief Description:

In this lesson students revisit the water cycle and model Earth's water reservoirs and fluxes.

Background knowledge / teacher notes:

All of the earth's water is contained in the system we call the hydrosphere. The subsystem includes the oceans, frozen water in glaciers and the ice caps, and other water such as groundwater, and the water vapor in the atmosphere. Wherever water occurs may be considered water's "reservoir." The biggest reservoir- the oceans hold 97.25% of the earth's water.

The Earth's Water Reservoirs		
Reservoir	**Volume (km^3)**	**% of Earth's water**

Oceans	1,320,000,000	97.21
Glaciers	29,200,000	2.15
Ground water and soil moisture	8,417,000	0.62
Lakes and Rivers	230,000	0.017
Atmosphere	13,000	0.001
Plants and Animals	< 10,000	< .00075
Total	1,357,870,000	100

Water Fluxes on Earth	
Process	**Volume of water moved (km^3/year)**
Precipitation into oceans	385,000
Evaporation from oceans	425,000
Precipitation onto continents (Precipitation that becomes ground water)	111,000 (16,000)
Evaporation and transpiration from continents	71,000
Transport of atmospheric water vapor from ocean areas to continental areas	40,000
Flow of surface, and groundwater into oceans	40,000
Total Flux / Year	1,072,000

More information on the water cycle and water budgets maybe found at NASA Earth Observatory. *The Water Cycle.*

Available: http://eob.gsfc.nasa.gov/Library/Water/

Lesson Description:

ENGAGE	Ask students to estimate how much water they might use in a typical day. Some figures are: shower- 20-30 gallons, tub bath - 30-40 gallons, flushing standard toilet- 3 gallons, machine wash one load of clothes- 20-30 gallons.

EXPLORE	Review with students the water cycle diagrams they completed in Unit I, or create a new systems diagram of the water cycle. Include the reservoirs (groundwater, water from lakes, rivers, oceans, and atmosphere as well as plants and animals) and the fluxes or processes that move water. (See above) Teacher Note: A flux is defined as a process that moves material from one reservoir to another at a particular rate. Define the area in which water fluxes will be measured. Use a local topographic map to outline the boundaries of the selected drainage basin. On a local scale, the water cycle can be described by a hydrologic budget equation that accounts for all the water that enters and leaves a given area. Ask students to write a word equation that balances the water budget in their region. Use the information on the water cycle to write the hydrologic budget.
EXPLAIN	Working in groups, calculate the fraction of the Earth's water that moves each year. Use the equation: Total fluxes/Total volume in reservoirs Use the data from your system diagram. More information on global water reservoirs and fluxes is available at the following site: University of California at Irvine. Earth Space System. *Global water reservoirs, fluxes, and turnover times.* Available: http://www.ess.uci.edu/~reeburgh/fig8.html

	***Journal Write*:** 1. What does the data show about the inflow and outflow from the oceans? 2. Calculate the water that enters and leaves the atmosphere each year. 3. Is there a balance? Support your answer using data.
EXTEND	How much time does water spend in a given place or reservoir? Use the equation: Residence time = reservoir size / total outflow to determine the average residence time for water in each of the reservoirs. <u>G/T/Technology Connection:</u> Apply the hydrologic budget to your area. Find information on your local area. Visit USGS. *Surf Your Watershed*. Available: http://cfpub1.epa.gov/surf/locate/index.cfm Things to think about: 1. Use a topographic map to determine your drainage area and calculate the area of the basin. 2. Determine the volume of precipitation for a calendar year 3. Determine the monthly evaporation data and extrapolate for the calendar year. 4. Calculate the volume of water leaving the basin as stream flow. 5. Determine the unaccounted for water.
EVALUATE	***Journal Write*:** Explain the earth's water budget and the structure of the hydrosphere in

	terms of reservoirs and fluxes. G/T Connection: How does the local water budget compare to the global water cycle in terms of reservoirs and fluxes?

Materials per lab group:

- Topographic map- four

The Earth's Water Reservoirs		
Reservoir	Volume (km^3)	% of Earth's water
Oceans	1,320,000,000	97.21
Glaciers	29,200,000	2.15
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Plants and Animals	< 10,000	< .00075
Total	1,357,870,000	100

Water Fluxes on Earth	
Process	Volume of water moved (km^3/year)
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Evaporation from oceans	425,000
Precipitation onto continents (Precipitation that becomes ground water)	111,000 (16,000)
Evaporation and transpiration from continents	71,000
Transport of atmospheric water vapor from ocean areas to continental areas	40,000
Flow of surface, and groundwater into oceans	40,000

Total Flux / Year	1,072,000

Resources:

University of California at Irvine. Earth Space System. *Global water reservoirs, fluxes, and turnover times.*
Available: http://www.ess.uci.edu/~reeburgh/fig8.html

USGS. *Surf Your Watershed*.
Available: http://cfpub1.epa.gov/surf/locate/index.cfm

NASA Earth Observatory. *The Water Cycle.*
Available: http://eob.gsfc.nasa.gov/Library/Water/